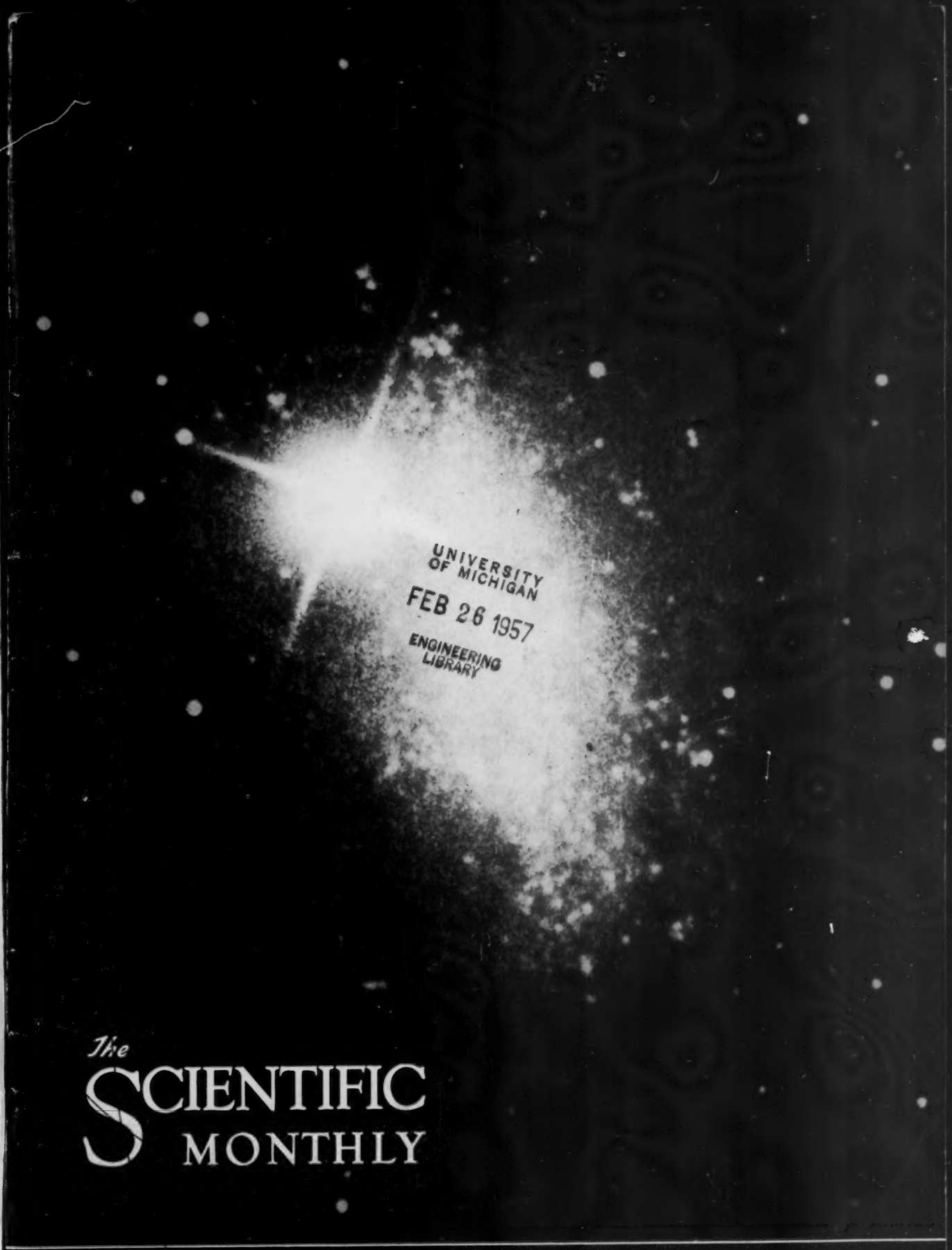

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Sorptive Minerals

A new bulletin, "Preparation of petroleum feeds for platinum catalysts," describes sorptive minerals that protect platinum used as a reforming catalyst for petroleum naphthas. Various minor feed constituents—for example, arsenic, tetraethyl lead, alkyl sulfur compounds, and nitrogen—that may poison the catalyst are removed by the new adsorbents. (Minerals and Chemicals Corp. of America, Dept. M56)

Polyethylene Glassware

New catalog describes many types of polyethylene glassware, including standard items as well as hydrometer jars, wide-mouth bottles, test tubes, centrifuge tubes, spigots, line valves, graduated cylinders, pipette baskets, and sink traps. (Scientific Glass Apparatus Co., Inc., Dept. M105)

Microprojector

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A manual describing the basic techniques of glass blowing on the glass lathe is available from Bethlehem. (Bethlehem Apparatus Co., Inc., Dept. M92)

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X-ray Microscope

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[*Courtesy David S. Evans, Royal Observatory, Cape Province, Union of South Africa, see page 122*]

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THE
SCIENTIFIC MONTHLY

MARCH 1957

An International Observatory

JOHN B. IRWIN

Dr. Irwin is professor of astronomy at Indiana University, Bloomington. He received his training at the University of California and the Lick Observatory, and he has taught at the University of Pennsylvania. He has been a guest investigator at the McDonald Observatory in Texas and also at the Mount Wilson and Palomar Observatories. His photoelectric researches have been extended to the Southern Hemisphere by means of trips to the Union of South Africa in 1950 and 1955. He made the latter trip as a Guggenheim fellow and worked at the Royal Observatory, Cape of Good Hope, and at the Radcliffe Observatory in Pretoria.

ABOUT 150 years ago, the great French mathematical astronomer Laplace wrote, "All astronomy depends upon the invariability of the earth's axis of rotation upon the terrestrial spheroid and upon the uniformity of this rotation" (*1*). The modern graduate student in astronomy, well versed though he may be in such fundamentals as radio astronomy, electronic computers, photoelectric photometry, stellar population types, interstellar polarization, expanding associations, coudé spectroscopy, and the like, will be puzzled, I am sure, by this quotation. His puzzlement will have little to do with and will be something far more fundamental than that arising from his knowledge that the earth's axis of rotation meanders over the surface of the earth and that the earth's rotation is not uniform but is a complicated and unpredictable function of time. Laplace, in turn, if he could suddenly return today, would be even more puzzled by the aforementioned listing of subjects.

Astronomy Today

Astronomy, like its sister science, physics, has grown almost beyond recognition in the last 150 years—or, more to the point, in the last 30 years. The relationship between astronomy and physics is now so close that most present-day astronomers think of themselves as astrophysicists rather than as astronomers, and rapid advances in physics often go hand-in-hand with similar advances in astronomy. Both sciences have as one of their main characteristic features the building and establishment of very large, expensive, powerful precision instruments. Not only have the results obtained from these large reflectors and accelerators been exciting, revolutionary, and fundamental; one should also recognize that such results could have been obtained only with the greatest difficulty, if at all, by less expensive, lengthier, and more conservative techniques.

It has been just 50 years since the Mount Wilson Observatory was established through the vision and leadership of George Ellery Hale, in the Sierra Madre high above the small village of Pasadena. The original 60-inch reflecting telescope is still going strong amid the pines and yuccas above the smog bowl, and the dead hand of obsolescence has been successfully avoided by continued intelligent development of auxiliary instruments such as spectrographs and photometers. The chain reaction, which under Hale's leadership and enthusiasm progressed from the 40-inch Yerkes refractor to the

60-inch, to the Mount Wilson 100-inch, and finally to the Palomar 200-inch is well known to astronomers and many other scientists.

Not so well known or appreciated are some of the by-products of this reaction. The 82-inch McDonald reflector in southwest Texas, for example, is a better telescope today because the difficult problem of supporting the 200-inch Pyrex disk—so that its figure holds to within a few millionths of an inch in all observing positions—was successfully solved. The 10-foot mirror of the $2.5 million, 120-inch Lick reflector, a telescope that should be in operation this year or next, was originally cast by the Corning Glass Company to be used in the testing of the 200-inch figure. The 98-inch Pyrex disk cast by Corning at the time of the successful 200-inch casting was generously given by the University of Michigan to the Royal Greenwich Observatory to be used in the Isaac Newton telescope. Bowen's fundamental analysis and solution of the problem of the large coudé stellar spectrograph that is fed by the 200-inch telescope will stimulate marked improvements in other such spectrographs and has already had reverberations in places as far away as South Africa. The 200-inch telescope made almost necessary a large survey-type of wide-angle camera, and the 48-inch Schmidt telescope at Palomar is now giving astronomers, for the first time, a very deep, exciting look at some three-fourths of the celestial sphere in both blue and red light. These are only a few specific examples; an extraordinarily large list of other instrumental and scientific advances could be compiled today and will be even larger tomorrow—advances stimulated by the construction and operation of the 200-inch Hale telescope.

This is the day of the large reflector, so much so that it has often been said and only partly in jest that the various gold medal awards of achievement should be hung on the telescope and not on the astronomer. It is difficult, although not impossible, to make a poor or ineffective observation with a telescope such as the 200-inch. If one glances through the list of those American astronomers who have been honored during the past 30 years by membership in the National Academy of Sciences, for example, one finds that the great majority of such astronomers have been associated directly or not very indirectly with the large reflectors in this country; and most of the minority members of this group were, or are, directors of observatories or astronomy departments where large funds, though not large telescopes, have been available.

The building of very large reflectors has been almost completely an American phenomenon; it has given astronomy here a character all its own. The scientific power of a large telescope is so great that one astronomer has estimated that, on the average, one out of every four astronomers in the world each year requests information or observations of one kind or another from the jointly operated Mount Wilson and Palomar Observatories. A roll call of those who make the pilgrimage to Pasadena each year would sound like an International Who's Who in astronomy.

The scientific world is greatly indebted to Lick, Yerkes, Carnegie, Rockefeller, McDonald, and a host of other American philanthropists who have made possible such observatories, observatories that have given us a deeper and more detailed understanding of the ever-mysterious universe. The observatories in this country have had the further not inconsiderable advantage—an advantage not enjoyed by observatories in northern Europe, for example—in having a good-to-excellent climate in the Southwest and along the California coast. Because astronomers must observe the stars from the bottom of an ocean of atmosphere, not only the quantity of observations is greater, but also the *quality* of observations is improved by locating in a good climate. This is even more true today than it was in the past. The larger we make our telescopes, the more sensitive they become to atmospheric turbulence or seeing. Modern photocells, for example, are so efficient that their effectiveness is either limited by the minute variations of the atmospheric transparency or, at the faint end of the stellar magnitude scale, by the quality of the seeing.

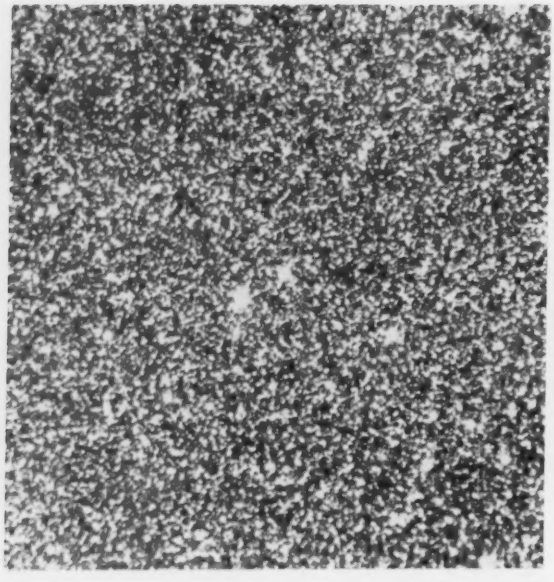
The competition between our all-too-few large observatories is great, as it should be. One is reminded here of the remark attributed to the Texas observing assistant who, in explaining to a group of visitors the outstanding features of the McDonald telescope, remarked: "And if it weren't for those blankety-blank Californians this would be the largest telescope in the world!" Competition is present, but so also is cooperation. Telescope time is expensive, and observing programs must be very carefully considered, not only in the light of yielding maximum results with a minimum of observing time, but also in the light of what the other fellow has done, is doing, and plans to do.

The Mount Wilson and Palomar Observatories have encouraged many competent outside astronomers to come as guest investigators and to use the 60- and the 100-inch reflectors and some of the other magnificent instrumental facilities insofar as these could be made available without interfering with the regular observatory programs. College professors naturally find it much easier to go

The southern Milky Way. This picture was taken by University of Wisconsin observers at Harvard Kopje with a 140-degree wide angle Henyey-Greenstein camera that was developed during World War II at the Yerkes Observatory. Our own galaxy (NGC Zero) is clearly shown with the characteristic nuclear bulge. The Small Magellanic Cloud, the Large Magellanic Cloud, and the bright star Canopus can be seen—reading from left to right—along the lower right edge. The south celestial pole is about an eighth of the way up from the center of the bottom edge. This section of the Milky Way, which also contains Alpha Centauri—the nearest star—the Coal Sack, the Southern Cross, and the Carina star cloud, is either invisible or observable only with great difficulty from the Northern Hemisphere observatories.

visiting during the summer months, so much so that despite the good summer climate in California, with consequent availability of large quantities of useful observing time, the demand for summer telescope time often exceeds the supply. The best seeing conditions also come during the summer months; hence, the local staff members have been known to remark that their guests use up the best observing weather. Many other instances of generous cooperation which follow this or somewhat different patterns can be found today in astronomy. I well remember my first arrival at McDonald Observatory, where I found a Belgian, an Italian, and a Danish astronomer sharing the observing time with the 82-inch reflector.

The question of whether there should be another 200-inch telescope built in this country is currently a subject of warm debate. Scarcely a dozen astronomers have observed with the 200-inch telescope; a few more have used some of the observational material. If one examines the membership list of the American Astronomical Society and picks out those American astronomers whose training would enable them to observe efficiently



A rich part of the Sagittarius star cloud near the center of our galaxy. This cloud is observable only with great difficulty from United States observatories, but it can be observed in the zenith at Pretoria. [Radcliffe Observatory photograph]

with the 200-inch telescope and whose present programs of research would be markedly improved by such observations, one would find at least 100 and perhaps as many as 150 astronomers meeting such criteria; and the names of many of our top-notch astronomers would not be present because of their special theoretical and observational interests. The conclusion is obvious: we badly need more very large telescopes in this country.

One of the earliest and most successful of the international scientific unions is the International Astronomical Union. There were 63 United States delegates at the 1952 IAU meeting in Rome and more than 100 at the 1955 Dublin meeting; the latter number is not a negligible fraction of the professional astronomers of this country. IAU meetings are well attended, and stay-at-home astronomers eagerly await the reports of the returning delegates and read with considerable care the lengthy *Transactions*. It would be difficult to find another science where cooperation on an international scale has been so successful and has played such a relatively major role.

Observation versus Theory

The role of the large reflector in modern astronomy has perhaps been here overemphasized. If one should make a list of the most important astronomical papers published in the last 30 years, I would not think that papers reporting observations made with large telescopes would make up more than one-third of the total of such a list, although "observational" papers would greatly outnumber "theoretical" papers. However, as Russell has pointed out: "The main object of astronomy, as of all science, is not the collection of facts, but the development, on the basis of collected facts, of satisfactory theories regarding the nature, mutual relations, and probable history and evolution of the objects of study" (*2*). Russell further remarks that, before a general theory can be attempted, sufficient data must be collected in the form of observations. The astronomer is faced with a choice: he can either (i) devote all his time to collecting large masses of observational material, as accurate and as extensive as possible, or (ii) he can keep the greater problems continually in mind and formulate his program of observation in such a way as to obtain observational data that bear directly on definite phases of these problems. The second type of observational approach is now the popular one and would seem to have it all over the first type of approach, and yet, surprisingly enough, the first type of approach has been spectacularly rewarding in the past.

The road to astronomical knowledge is not a broad, royal highway but is often a tortured, twisted, many-branched trail where no man can be sure of the next destination. Examples are surprisingly numerous. Tycho Brahe spent most of his life observing the positions of stars and planets with the highest possible pretelescopic accuracy, and he discovered atmospheric refraction. His observations, which would have been rejected out of hand by the modern observer, were used by Kepler to discover the laws of planetary motions, which in turn enabled Newton to formulate the law of universal gravitation and, as a by-product, to proceed with the development of the calculus.

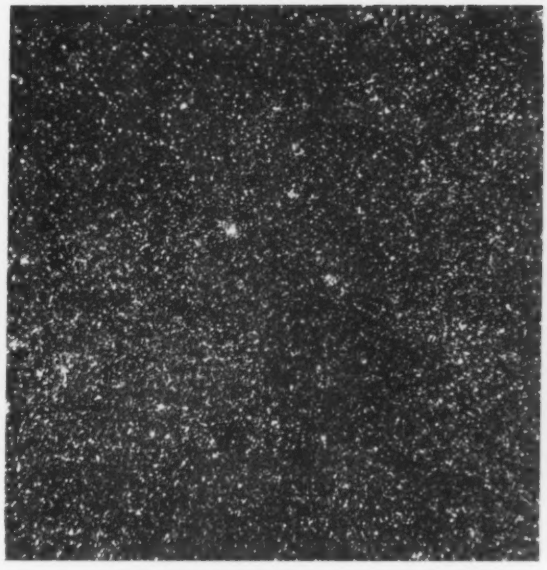
Roemer assiduously observed the satellites of Jupiter for navigational purposes and came up with the velocity of light. Bradley observed the positions of stars for parallax and found stellar aberration. John Goodricke spent many nights examining the brighter stars for variability of light and discovered scarcely a handful that were periodically variable; these few discoveries, however, initiated the study of eclipsing and cepheid variables which led us in turn to the knowledge of how to measure accurately the diameters of stars, and also to measure, with some confidence, distances out to more than a billion light-years. William Herschel embarked on a lengthy program of observation of double stars, in order to determine stellar parallaxes, and the binary orbits he dis-

covered later yielded the masses of the components; more than a century later, these masses made possible the discovery of the mass-luminosity relationship that further made it possible to derive dynamical parallaxes from double-star observations! Trumpler's necessarily inaccurate determinations of the diameters of star clusters led to the fundamental knowledge of general galactic absorption. More recently, Chandrasekhar's prediction of the partial polarization of light from the limb of a nearly eclipsed star led to the discovery of interstellar polarization.

All through the 19th century and up to the present time, hundreds, nay thousands, of astronomers have slaved away, observing the positions of stars and planets with meridian circles. From these copious data have been extracted such unexpected jewels of knowledge as the identification and distances of moving clusters of stars, the zero-point of the period-luminosity law, the rotation of the galaxy, the asymmetry of stellar motions, various kinds of statistical parallaxes, the motion of the sun with respect to the nearby stars, the kinematics of stellar population groups, the variation of latitude, the variability of the earth's rotation, and, most recently, Blaauw's (*3*) discovery of expanding stellar associations from which the ages of stars can be derived with considerable certainty. This is only a partial list; there are also almost certainly still undiscovered treasures in the data. This is exactly the type of work that has now become so unpopular; and yet more observations and more precise observations of position are admittedly needed to solve some of our most important astrophysical problems.

An entirely different viewpoint can also be taken. An accurate knowledge of the motions of hundreds of thousands of stars is so fundamental in our theories of stellar motions and galactic structure that from the viewpoint of the astronomer of the year A.D. 2057 what is needed is far greater observational accuracy *at the present time*. It would seem to be quite possible to determine the positions of 300,000 or more stars with an error of ± 0.03 second in each coordinate, provided that modern photographic and computational techniques were used along with meridian circle observations of reference stars. The cost would be x million dollars, where x is some number greater than unity. It would be far less expensive and less laborious to determine these same positions with an error of, say, ± 0.12 second.

The value of the less precise positions would be almost as great *now*, insofar as advancing our *present* knowledge of stellar motions is concerned, as positions 4 times more precise. The factor of 4 in accuracy would, however, be fully operative 100 years hence and might well be of critical importance in a variety of investigations at that time. Just as we owe a tremendous debt to astronomers of the past century for supplying us with so many basic data, so should we also make every reasonable effort now to assist the as yet unborn astronomer by supplying him with the best possible observational data, data that *must* be obtained for him *now*. This philosophic approach is a far cry from that practiced by the modern astrophysicist, who must concentrate his observing efforts into a few nights a year with a large reflector; and yet both approaches are necessary and have their rightful place in astronomy.



Part of the Small Magellanic Cloud. These stars and star clusters can be studied effectively because they are all at the same distance. The brightest stars shown are supergiants plus a few foreground objects. [Photograph by D. S. Evans with the 74-inch Radcliffe reflector; courtesy Royal Cape Observatory]

One of the most encouraging aspects of this astrometric problem is that a large percentage of the observational and computational work can be left now to easily trained technical assistants operating nearly automatic plate-measuring devices and punched-card machines (*4*). Such techniques not only reduce costs and speed up evaluation time but also eliminate much of the "deadliness" of such routine programs. I am not one of those who feel that an astronomer working year after year in the same old methodical way thereby necessarily incapacitates himself for evaluating fully the scientific results of his program, even though I must acknowledge that the evidence against me is very strong.

Advances in Instrumentation

Ignoring radio astronomy, which is almost a science unto itself, let us consider briefly some of the other basic observational fields such as sky-mapping (direct photography), spectroscopy, and photometry. The needs and operational methods in each of these fields are quite different one from the other and also from those to be found in astrometry. Our wide-angle astronomical cameras have grown larger and more powerful with the years and have reached their present peak size and performance in the $250,000 48-inch Schmidt telescope at Palomar Mountain. Thanks to financial support from the National Geographic Society, it has been found possible to make a complete two-color survey of that part of the sky which is effectively observable from Palomar.

Nearly 100 copies of the original set of plates (879 blue and 879 red exposures) are now being distributed to the world's observatories at a cost of about $2000 a set, or a little more than a dollar a print, a price that covers only the bare costs of printing. One would find it impossible to predict with any sort of accuracy either the number or kinds of results that will be extracted from the fantastic amount of information available on these prints. This is a precision survey. The number of rejected exposures has been large, and the observing program has been markedly lengthened because of the high standards that have been insisted upon. No other sky survey can even come close to this one in the matter of scale, depth of penetration, definition, standardization control, and color information. There is no question, however, but that a Schmidt telescope twice or more than twice as large as the 48-inch could be built successfully and could give us a decidedly better over-all look at the universe. Such an instrument would be much more costly, the optical and mechanical problems would be difficult—but not impossible—to solve, the angular field of view might be only half as great, necessitating 4 times the number of plates, and, worst of all, the telescope would be more sensitive to poor seeing conditions. This is, however, such an obvious fundamental technical advance that it would appear to be only a question of time until two such cameras are financed and built, one for each hemisphere.

The interesting triple system of southern galaxies, NGC 6769, 6770, and 6771 shows some evidence of tidal distortion. [Photograph by D. S. Evans with the 74-inch Radcliffe reflector; courtesy Royal Cape Observatory]

Stellar spectroscopy is a field in which the large reflector reigns almost supreme. The larger the mirror, the greater the dispersion (and, hence, information) that can be used at any magnitude level, other things being equal. The larger the mirror, the shorter the exposure time at a given dispersion—a not inconsiderable advantage in the study of variables of short period. The larger the mirror, the fainter the star that can be observed with a given dispersion. The larger the mirror, the fainter the star whose spectrum can be observed at all. These statements need some qualifications. For example, for very high dispersions, all large reflectors—from about 100 to 120 inches on up—are equally effective, or, rather, equally ineffective; their relative efficiency is determined by the efficiency of the spectrograph—which goes up with size—and by the seeing conditions.

At long focal lengths, the stellar images act like illuminated surfaces rather than point sources; very little of the starlight can get through the necessarily narrow slit jaws. This condition will undoubtedly lead to the development of even larger, more expensive, but more efficient, grating spectrographs. The slit spectrograph operates under the further disadvantage that only one star can be observed at a time. For these reasons, spectral *survey* programs have been efficiently carried out —even in poorish climates—by means of an objective prism. The prism is mounted in front of a comparatively small, wide-angle telescope; numerous stellar spectra are visible on each plate, and there is no loss of light through a slit. This tech-

The brightest star near the center of the southern galactic cluster Messier 25 is the cepheid variable U Sagittarii. The absolute luminosities of such pulsating stars are of critical importance in the distance scale of the universe. The luminosity of this cepheid can be determined with high precision—if it is a cluster member—by photoelectric and spectroscopic observations of the cluster stars. The next most favorable case of this sort is also in the Southern Hemisphere. [Royal Cape Observatory photograph]

nique was used with marked success at the Harvard College Observatory in the formation of the great Henry Draper Catalogue of stellar spectral classification, and, more recently, it has been effectively applied, for example, by astronomers at the Warner and Swasey Observatory of Case Institute of Technology in exciting modern spectroscopic researches pertaining to galactic structure. In this connection, I should also mention the new 31½-inch Schmidt telescope of the Hamburg Observatory. This instrument, with its excellent Zeiss optics, is undoubtedly the most effective telescope in Europe today. Because a few hours' observing with this powerful wide-angle camera equipped with an objective prism can give unique observational material requiring months of evaluation time, such a telescope would seem to provide, at first thought, the perfect solution for what to do in a very poor climate. It should be emphasized, however, that the solution is only a *partial* one and that complete and often decisive evaluation of such observational material further requires both photoelectric photometry and slit spectroscopy with a giant reflector. The 120-centimeter spherical mirror of the Hamburg Schmidt, the largest mirror now in use in Europe today, is not quite as large as one of the mirrors in the Palomar coudé *spectrograph*.

Large reflectors can also act as giant cameras, but the angular field of view is so small that it would take tens of thousands of years to cover the whole sky in even one color. The observational fields of both direct photography and stellar spectroscopy with large reflectors will be completely revolutionized in the next 10 to 20 years, in my opinion, by the application of television techniques

whereby a photoemissive cathode is used in combination with photographic registration. Photoelectric surfaces are some 100 times more efficient than the best photographic emulsions, and gains of from 2.5 to 5 magnitudes might be expected, provided only that practical techniques are perfected. Baum states (*5*), "If the full advantage of photoelectric quantum efficiency could be ideally utilized, it would theoretically accomplish what unaided photography would need a 2,000-inch telescope at F/3.67 to do." The real villain in the case is, however, the seeing; if some method of seeing compensation could be made practical, such as the Eidophor technique (*6*) in which the effective figure of the primary mirror is indirectly and automatically continuously distorted in order to "match" the seeing distortions, a rather fundamental, if not revolutionary, step forward would be made.

The revolution that we hope will happen in spectroscopy is already happening in astronomical photometry, thanks to the development of the multiplier phototube to a high state of perfection. The photoelectric cathodes in these photomultipliers are so sensitive that the astronomer not only can measure precisely the light of stars that he can see in the eyepiece but can also go very much fainter and can—with some difficulty—measure invisible stellar images, images that do not register on the best photographic plates at all. The photocell has always been highly precise and reliable for those objects that were bright enough; it now has the requisite sensitivity, at least at the usual photographic and visual wavelengths. The brightness of a star is difficult to measure with any degree of accuracy, either by eye or by means of a photographic plate, especially over a range of brightness of from 1 million to 10,000 million. Photoelectric currents, on the other hand, can easily be measured to 0.1 percent—about one one-thousandth of a magnitude—and the limitation of accuracy in stellar photoelectric photometry is, in general, set by the atmosphere. The precise determination of color, so important in researches where interstellar and intergalactic reddening are involved, is a comparatively simple matter photoelectrically and an almost impossible problem photographically. The photographic plate has been described by one astronomer as the most frightful photometric device ever devised by the mind of man. We are delighted to be emancipated from its tyranny. However, photographic photometry is not obsolete by any manner of means. Accurate magnitudes and colors of thousands of stars in a cluster or in a rich star field can be derived from a few photographic exposures by photoelectrically observing a comparatively few of the stars as calibration standards.

The photoelectric situation may be summed up in a few sentences. Atmospheric requirements are now so stringent, with regard to both quantity and quality of clear sky, that many observatories that have specialized in photometry in the past are literally "out of business" in this field of observation. Basic observational data of colors and magnitudes which are of modern quality are almost nonexistent. Much of the older photometric work badly needs redoing, and there is also an ever-increasing entirely new set of photoelectric problems that are appearing and require urgent attention. Although the large reflector is still supreme at the faintest levels, most of the photoelectric observational problems can be more quickly and accurately solved with small- to moderate-sized reflectors. (The force of this statement can be amplified by noting that the difference in cost between a 20-inch and a 200-inch telescope is a factor of about 1000!) The photoelectric limitation that only one color of one star can be observed at a time can be and has been overcome, in part at least, by intelligent and advanced instrumentation. Finally, precise photometry is so fundamental in so many branches of astronomy, ranging all the way from the physical structure of individual stars to the distances of galaxies on the edge of the observable universe, that its importance can scarcely be overrated.

Southern Hemisphere

One of the peculiar features of our telescopic facilities is the complete unbalance between the Northern and Southern Hemispheres. There are now six reflectors larger than 61 inches in the north and only two—the 74-inch Radcliffe reflector at Pretoria and a similar reflector at Canberra—in the south. There are no southern counterparts of the 200-inch reflector or the 48-inch Schmidt at Palomar. The unbalance extends even for smaller instruments and observatories and will be even greater when the 120-inch Lick reflector goes into operation. A physicist or chemist might well ask, What's the difference? A northern meson or proton is pretty much the same kind of beast down south. But this is not true of the stars.

The Southern Hemisphere contains the brightest and in some ways the most interesting part of the Milky Way, including the galactic center and inner spiral arms; it also contains the two Magellanic Clouds, our two nearest extragalactic neighbors. The Magellanic Clouds, for example, present a unique opportunity for the study of stars of great

luminosity. There are some 1000 stars in the Large Magellanic Cloud, each of which has more than 15,000 times the candlepower of the sun. Their luminosities and diameters can be accurately determined, because the distance is known, but, surprisingly enough, we know only partially which stars these are at present. The problem of weeding out the background supergiants from the foreground stars is simple enough, but the detailed study of their spectra would require a very large reflector. Such a study would be especially rewarding, because here one would be studying the behavior of matter under highly exceptional physical conditions. The Magellanic Clouds are at about one-tenth of the distance of the Andromeda Nebula, which has been studied so long and so profitably by the Mount Wilson and Palomar observers. A 200-inch reflector down south would, in this comparison, be as effective as a 2000-inch northern reflector.

The Southern Hemisphere problem is well known. For example, Otto Struve, president of the International Astronomical Union, mailed a circular letter in 1950 to a large number of well-qualified astronomers asking them for their ideas concerning "the things to come" in astronomy. He reported (7), in a paper that should be required reading for all budding and full-fledged astronomers, as well as administrators of scientific funds, that "nearly one-half of the replies urge that more effort be made in the Southern Hemisphere. . . ." American astronomers, collectively and singly, have trekked south on numerous occasions in attempts to fill the void and acquire badly needed observations. American observatories have been established, especially in the good climate of South Africa, on a permanent or semipermanent basis. These observatories have done remarkably well, notwithstanding the fact that they have been skimpily staffed and have suffered severely from isolation. For example, one of the most fundamental empirical correlations in stellar astronomy, the cepheid period-luminosity law, was discovered from plates taken of the Small Magellanic Cloud at a Harvard Southern Station.

It is to be hoped at this point that the reader will have some understanding of the international character of astronomy, of the strange twists that astronomical researches often take, of the unique power of instrumentation—both of the costly giant reflectors and the necessary, but smaller, more specialized telescopes—of the spectacular new auxiliary tools that the astronomer now has or that he shortly may expect, and finally, of the opportunity and need for observations in the Southern Hemisphere. One other major point is that there is a large reservoir of exceptionally well-trained astronomical talent in Europe which at present has only very limited access either to large reflectors or to a good observing climate; this is also true for the many middle western and eastern astronomers in this country.

An obvious solution would be the establishment of a number of top-notch observatories in the clear skies of South Africa or South America, observatories financed and operated by the various interested Northern Hemisphere nations and universities. Not only would such observatories create badly needed observational outlets for American and European astronomers in a place where research opportunities were never brighter, but they would also be a long step forward in equalizing the intolerable hemispheric unbalance which has plagued our science for all too long.

Cogent reasons of this sort are behind the recent announcement of provisional plans for the establishment in South Africa of a joint European southern observatory, an observatory to be sponsored by astronomers from Belgium, France, Great Britain, the Netherlands, Sweden, and West Germany. The project will be an ambitious one, with plans for a 120-inch reflector, a 48-inch Schmidt telescope like that on Palomar, and possibly a meridian circle. The latter instrument is especially to be desired in view of the fact that there are now only two meridian circles in the entire Southern Hemisphere with which astronomers are actively observing and publishing results of large-scale programs. This sort of investigation is far too important and fundamental; its continued neglect in the Southern Hemisphere would be a very serious matter, especially at this time when repeat observations of stellar positions would yield proper motions of a new and often decisive order of accuracy. Some site-testing for this proposed observatory has already been done at stations in the Karroo and on the high veld. When and if such an international observatory materializes, it would be a magnificent step forward in man's attack on the problems of the universe.

But what of the United States in all this? The southern observatory situation has unfortunately deteriorated in the past few years from the American point of view with the closing down of the University of Michigan's Lamont-Hussey Observatory and the near abandonment by Harvard College Observatory of its Boyden Station on Harvard Kopje near Bloemfontein. It is tragic that this deterioration has taken place just at a time when the whole trend of galactic and extragalactic research

has pointed up the superiority of the southern skies and at a time when communication and travel over long distances have become so rapid and efficient.

For the Northern Hemisphere, the National Science Foundation not only has announced plans for a very large radio observatory at Green Bank, West Virginia, but is also going ahead on a 5-year program of planning, site-testing, and building for a new American observatory in the Southwest. Four sites in Arizona and one in California are currently being tested in hopes of finding the site with the best annual yield of clear night hours and a high average of good seeing. A 36-inch reflector should be in operation in a year's time, and an 80-inch reflector should be completed at the end of the 5-year program. At that time the question of a considerably larger telescope will be explored. It would be an understatement to say that these plans and possibilities are very encouraging; but it is clear that, no matter what telescopes are set up in the Southwest, such instruments will often provide only partial answers if the Southern Hemisphere is neglected.

International Observatory

With these things in mind, it would seem to be high time to start planning for a new international observatory, an observatory operated by American astronomers but located either in South Africa, South America, or Australia, an observatory that would take full advantage of the most unusual observing opportunities to be found in the southern skies. The long experience of our astronomers in building, operating, and observing with large reflectors would be of tremendous advantage. So too would be the opportunity of cooperating with observatories in this country on basic observational programs of an entirely new order of quality and importance, programs covering the entire sky.

This observatory should be equipped with the best possible telescopes, telescopes specifically designed for every important type of observational work. As a starter and as a point of departure, one might suggest a 200-inch reflector, or even something larger, a 96-inch Schmidt, an 80-inch reflector, a number of smaller reflectors and Schmidts, and a variety of more specialized instruments. There is no question but that such telescopes can be built, and if they were efficiently operated in the Southern Hemisphere, they would have a truly profound effect on the science of astronomy. The rewards would be rich indeed.

There are many advantages in having smaller telescopes at such an observatory. Spectroscopic observations with a half-size telescope might take 4 times as long in exposure time, but the telescope would be one-eighth as costly, and the assessment time would be the same for either telescope—a matter of days or weeks. Problems tend to pile up on the largest reflectors with their unique power at the faint end of things, and observing time must be carefully rationed, so that smaller and less costly telescopes should be used whenever possible, and they could help to relieve the pressure on the "giants." Many programs of observation are better done with smaller telescopes. For example, a sky survey too lengthy for a large Schmidt might be quickly completed with a smaller Schmidt able to photograph a much larger area of the sky on each plate. Badly needed photoelectric colors and magnitudes of the 100,000 brightest stars could be obtained more quickly and more accurately with a 20- or 24-inch than with a 100-inch reflector. An astronomer making the long trek to South Africa might well find that he could use the large reflector only one night out of five or ten, and he would find it highly desirable to supplement his work by observing with smaller instruments. A large reflector may be 10 to 30 years in the building, which is a long time to wait for a "going concern"; smaller telescopes could be ready for operation as soon as the site was finally chosen. An international observatory should serve dozens, if not hundreds, of astronomers, and a logical solution would seem to be to build at least half a dozen or more moderate-sized instruments in addition to the very expensive large reflector or reflectors. The National Science Foundation's preliminary plans for the Southwest observatory might well be criticized on this point; there are just not enough telescopes.

There would be many special problems connected with and peculiar to the building and operation of such an international observatory. The main problem, the fundamental stumbling block, is, of course, the financial problem. If this could be solved satisfactorily, the solution of the technical and personnel problems could be made comparatively simply. One of the biggest mistakes that could be made in the establishment of such a large observatory would be in setting the sights too low and in underestimating the cost of construction and operation. The total cost of the scientific effort connected with either the Mount Wilson and Palomar Observatories or the Lick Observatory, for example, is well in the hundreds of thousands of dollars a year; one does not get something for nothing.

One must also here recognize two peculiar problems; (i) the large distances to the Southern Hemisphere from this country with consequent sub-

stantial travel expenses and (ii) the comparative scientific isolation. Much of the success of the observatory would depend on the instrumentation that would have to be continuously developed, and such development must of necessity be the responsibility of the observatory staff and would therefore take place at the observatory. It would scarcely suffice to make "carbon copies" of existing American telescopes, spectrographs, and photometers and then to call it quits. In such an event, much of this so-important auxiliary equipment would be obsolete in 10 years' time.

Consider the problems facing the hypothetical director of our imaginary observatory. He is a distinguished scientist with a well-deserved international reputation arising from his brilliant and varied researches in galactic dynamics, binary star orbits, radiative transfer, stellar spectroscopy, and the relativistic theory of the expanding universe. He speaks half a dozen languages fluently, including Russian. His observatory is situated in the high veld on the edge of the Karroo, and never before has he seen such a transparent sky or such a glorious Milky Way. His main telescope is larger by far than any other in the Southern Hemisphere, and its coudé spectrograph—the heart and soul of this telescope—is the finest that money can buy and is ready to go. His staff of assistants is quite adequate to "keep the telescope in running order" and to help keep the numerous visiting astronomers well fed and happy. In the first few months of operation, he finds that his spectrograph needs in succession an image rotator, a photoelectric exposure meter, an automatic guider, a moonlight eliminator, spectrophotometric standardization equipment, a device so that guiding drift can be made at any prescribed angle, a spectrum widener, an off-axis guider, a photoelectric spectrum scanner, and an image-slicer.

The director cannot order these things from the nearest ironmonger, nor should he have to wait until such devices are in common use elsewhere. One could argue that these things are mere gadgets, able at best to improve only somewhat the quality and quantity of the stellar spectra so obtained. The truth is, however, that such gadgetry would make possible scores of critical investigations otherwise impossible. Our harassed director would feel even more harassed on hearing that it was now possible to turn out precision gratings 40 inches square; he would realize that his spectrograph would need complete redesigning in order to gain this new factor of 4 in speed. Imagine his feelings when he learns that new television techniques have been perfected that will enable him to go 5 magnitudes fainter—just as soon as such complicated equipment can be built and installed.

One could do far worse than to emulate George Ellery Hale's approach to this fundamental problem. Hale not only surrounded himself with numerous first-class optical, mechanical, and instrumental technicians; he also employed optical and instrument engineers and engineering draftsmen. A good physical laboratory and grating-ruling machines, as well as optical and machine shops, were an integral part of the Mount Wilson Observatory. If Hale were alive today, he would almost certainly consider that electronic engineers and technicians, along with computing experts and machines, are necessary additions to a successful modern observatory.

This type of operational approach would obviously be even more essential to an observatory that would be so distant from the scientific centers of Europe and the United States. The cost would be high, but the rewards would be even higher; and if the primary instrument is to be a large expensive reflector, these additional costs would be proportionately small.

The adequate financing of astronomical research is a matter of deep concern to all astronomers, both here and abroad. The number of men in the world who could personally finance the building of "the largest telescope" are few, and their numbers are diminishing. The American multimillionaire is becoming something of a *rara avis*. There are only a few foundations with assets of more than $20 million whose funds are not committed. One hesitates to rely on military funds for long-range basic research, even if such funds could be made continuously available in the necessary amounts. In this day and age when the word *Palomar* is well-known to high-school students the world over, I have often wondered why it is that governments almost insist that their observatories be well stocked with mediocre and obsolescent equipment, when, for the price of a few miles of superhighway, any one of a score of responsible governments could build a second or third Palomar, or a southern Palomar, or a larger Palomar. And for the cost of a few more miles of superhighway, a foundation could be established that would keep such an observatory adequately staffed and up to date almost indefinitely. Let us hope that the present situation will soon change, both here and abroad.

Astrophysical research is not for those who want "practical" results right away or in a few years. It is difficult to present adequately or to evaluate accurately the case for such basic research and to demonstrate the great power of the indirect ap-

proach. The cause-and-effect relationships that exist, for example, between the discovery of the mass-luminosity law and modern atomic-energy developments, between Adams' necessarily poor spectroscopic observations of the companion of Sirius and the correct theory of the flow of electrons in metals, or between Bernhard Schmidt's revolutionary wide-angle telescope and modern television receivers, are tenuous indeed; but these relationships *are* there and, like the proverbial fur coat in the traveling salesman's expense account, are not apparent at first glance. However, such relationships —and countless others—can be traced all through the history of science, and it would be folly to ignore or minimize the value of the study of the universe, a study that has done so much to help man learn how to live in this universe.

References

1. S. Laplace, *Méchanique Céleste,* vol. 5, p. 22; quoted by C. L. Doolittle, *Proc. Am. Assoc. Advancement Sci.* **42**, 31 (1893).
2. H. N. Russell, *Proc. Natl. Acad. Sci. U.S.* **5**, 391 (1919).
3. A. Blaauw, *Bull. Astron. Inst. Netherlands* **11**, 405 (1952).
4. J. Lentz and R. Bennett, *Electronics* **27**, No. 6, 158 (1954).
5. W. A. Baum, *Astron. J.* **59**, 314 (1954).
6. H. W. Babcock, *Publ. Astron. Soc. Pacific* **65**, 229 (1953).
7. O. Struve, *J. Franklin Inst.* **251**, 13 (1951).

Bright Galaxy

Our cover this month shows the galaxy IC 5152 as it was seen through the 74-inch reflecting telescope of the Radcliffe Observatory, Pretoria, South Africa. The bright blue stars in the galaxy are well resolved, and this galaxy may be associated with, and be as close to us as, the Magellanic Clouds. (See page 118 of this issue.) The large image alongside the nebula in the photograph is the brightest star, which is of seventh magnitude and is a foreground star. The structural details which it shows (rays and ring) are artifacts produced in the optical system of the telescope (in common with most other large telescopes). The photograph was taken by David S. Evans of the Royal Observatory, Cape Province, Union of South Africa, and is reproduced here by courtesy of the Royal Observatory.

Silverfish, a Paper-Eating Insect

REUBEN LASKER

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SILVERFISH eat paper. Since these insects are viewed with dismay by almost every housewife and with horror by most librarians, it is strange that they have been studied so little. One of the earliest scientific reports written about the silverfish (probably *Lepisma saccharina*) was that of Robert Hooke, who published the following account in *Micrographia* in 1665 (*1*).

"The animal probably feed[s] upon the paper and covers of books, and perforates in them several small-round holes, finding, perhaps, a convenient nourishment of hemp and flax, which have pass'd through so many scourings, washings, dressing, and dryings, as the parts of old paper must necessarily have suffer'd; the digestive faculty, it seems, of these little creatures being able yet further to work upon these stubborn parts, and reduce them into another form.

"And indeed, when I consider what a heap of saw-dust or chips this little creature (which is one of the teeth of Time) conveys into its intrals, I cannot chuse but remember and admire the excellent contrivance of nature, in placing in animals such a fire as is continually nourished and supply'd by the materials convey'd into the stomach, and fomented by the bellows of the lungs; and in so contriving the most admirable fabrick of animals . . . ."

A reproduction of Hooke's original drawing of the silverfish, which accompanied his report, is given in Fig. 1.

The problem for the biologist who is interested in silverfish nutrition can be clearly stated with Hooke's help. What is the "fire" that enables this "most admirable fabrick of animals" to "work upon these stubborn parts, and reduce them into another form"?

In the years since Hooke's original observations, a few other investigators have studied the feeding habits of the silverfish (*2*). The most complete work was that of Lindsay (*3*), who found that the silverfish *Ctenolepisma longicaudata* preferentially attacked paper materials containing a sizing such as starch, dextrin, casein, or paste rather than paper without these. The paper-eating habit is a unique one, for paper is made from wood pulp, which is composed mostly of cellulose, a polysaccharide of glucose that is digested by very few animals. The organism also preferred chemically degraded cellulose to pure cellulose. Lindsay's experiments suggested that the animal is capable of distinguishing substances through its labial palps, which contain sensory papillae.

The digestion of cellulose was assumed by Lindsay because he was able to keep silverfish alive longer on a diet of cellulose than he could when they were starved. He cultured cellulose-decomposing bacteria from a part of the intestine of a single animal, the crop, and concluded from this that symbiotic microorganisms of the gut were responsible for any cellulose digestion that may occur in silverfish. Microorganisms (bacteria or protozoans) may sometimes be provided a home in the intestine of an animal and there may digest refractory materials that the animal cannot digest. By-products of this digestion or the bodies of the microorganisms themselves may serve as nutriment for the animal. In this way, a mutualistic relationship or symbiosis may be established which benefits both the animal and the microorganism.

Information from several sources, including visual observation, indicated to other workers that silverfish consume large quantities of carbohydrate materials but also eat nitrogenous materials when they are available. Cellulose appeared to be the carbohydrate eaten in greatest amounts, but it was not clear whether cellulose was truly digested or to what extent symbiotic microorganisms were implicated in this digestion.

In 1954 a research program was initiated in the laboratories of the department of biological sciences of Stanford University to investigate silverfish (*4*). This investigation was guided by the following questions, which are amplications of Hooke's original one: (i) Does the silverfish digest cellulose? (ii) If so, how does digestion of cellulose

Fig. 1. Hooke's original drawing of the silverfish [from *Micrographia*, 1665.]

occur in this animal and to what extent are symbiotic microorganisms of the gut responsible for this digestion? (iii) How does feeding on a high carbohydrate diet affect this animal's utilization of nitrogen?

All of the following work was done with the silverfish *Ctenolepisma lineata* as the experimental animal. Details may be found in several reports (*5, 6*).

Digestion of Cellulose

The respiratory quotient (RQ) is a convenient way of expressing the metabolism of an animal. When a pure carbohydrate such as glucose is metabolized, as much carbon dioxide is evolved as oxygen is consumed. Hence the ratio of carbon dioxide to oxygen is close to unity in this case. Proteins and amino acids, when they are metabolized, give figures less than one. Early in this investigation, it was found that silverfish that are fed on a diet of pure filter-paper cellulose for 1 month or longer have respiratory quotients ($RQ = CO_2/O_2$) very close to 1.0. If the diet is a pure protein like gelatin, the RQ of silverfish drops significantly and ranges around 0.75. This seemed to indicate that pure carbohydrate (cellulose) is being metabolized almost exclusively in the former case.

One standard method used by animal physiologists for determining the digestibility of a foodstuff is that of digestibility coefficients. Here the dry weights of the food and the feces are determined, and the percentage digestibility of the foodstuff calculated by the formula (*7*):

$$\text{Percentage digestibility} = \frac{\text{dry wt. of food consumed} - \text{dry wt. of feces}}{\text{dry wt. of food consumed}} \times 100$$

If complete digestion of a foodstuff were to occur, no excrement would be produced, and the coefficient as defined by this method would equal 100 percent. Maynard (*8*) found that the dairy cow has a digestibility coefficient of 72 percent when it is fed dried grass. Typical values for insects include 24 percent for the silkworm larva that is fed on mulberry leaves; 48.5 percent for the army worm *Prodenia eridania;* and 46.3 percent for the meal worm *Tenebrio molitor* (*7*). The lower values for the plant-eating insects probably reflect their inability to digest the cellulose portion of their diet. When a series of silverfish were fed pure filter-paper cellulose, their digestibility coefficients (72 to 87 percent) revealed that cellulose was digested to a degree approximating, and in many cases exceeding, that of the dairy cow (72 percent). In addition, *Ctenolepisma lineata* gained weight for a period of a few weeks on a diet of cellulose alone.

To prove conclusively that the silverfish is capable of metabolizing cellulose after its ingestion, the digestion and utilization of cellulose containing carbon-14 was studied. After the animal had fed on C^{14}-cellulose, the carbon dioxide given off by the animal was tested for radioactive carbon. This respiratory carbon dioxide was highly radioactive and provided direct proof that cellulose was digested and metabolized. The evidence obtained with the carbon-14 method and that described previously indicate that cellulose is digested and metabolized with high efficiency by the silverfish. Incorporation of C^{14}-cellulose was shown by the results of an examination of the silverfish tissue for radioactivity. Glands and muscle were radioactive, which showed that incorporation of the carbon derived from cellulose does occur.

Role of Symbiotic Microorganisms

The importance of intestinal symbiotic microorganisms for the digestion of cellulose in ruminants and some insects is a known fact (*9*). It was necessary therefore to determine whether or not there were any symbionts in the intestine of the silverfish which might play a similar role. The silverfish intestine is free of the type of modification seen in those organisms that provide "fermentative chambers" for symbiotic microorganisms (*10*). Microscopic examination of the intestinal contents of *Ctenolepisma lineata* does reveal some bacteria, which would be expected. However, enrichment cultures made to obtain cellulolytic bacteria—that is, bacteria capable of breaking down cellulose—were unsuccessful, although cellulolytic molds could be grown from gut contents on occasion.

Hungate's critical techniques were employed without success for the culture of cellulolytic microorganisms that live in the absence of oxygen. Both anaerobic and aerobic culturing soon made it clear that the microorganisms of the silverfish intestine were intolerant of anaerobic conditions. This might

be expected, considering the small size of the animal, its extensive tracheal system, and the absence of any modification of the gut which might harbor dense groups of microorganisms. The highest number of microorganisms found in a silverfish (2×10^5) is not comparable to the populations found in animals where an active symbiosis takes place.

From these lines of evidence, it must be concluded that intestinal bacteria play an unimportant role in the digestive processes of the silverfish, *C. lineata*. Molds are never seen growing in the gut of this animal. Probably occasional spores are ingested when the animal grazes on cellulose, and these can then be cultured from the intestine.

It is not unusual to find some protozoans in the midgut of the silverfish. Many workers have reported the occurrence of gregarine parasites in silverfish (*11*). In *C. lineata*, these were occasionally found, but rarely in a density of more than 15 per animal. Considering the parasitic nature and the sporadic occurrence of these sporozoans, they cannot be implicated in cellulose digestion by the silverfish.

Only intracellular symbionts remain as a possible outside source of the cellulolytic activity found in the silverfish. Intracellular symbionts have been described for many insects, including roaches, ants, primitive termites, and others (*12*). The most successful study of an insect that was artificially deprived of its intracellular symbionts is the work of Brooks and Richards (*13*) on the German cockroach. Most insects that have intracellular symbionts, like the roach, have discrete morphological entities called mycetomes which are located in the fat body and contain so-called "bacteroids" or bacterialike particles. The method of transmission of these bacteroids to the embryo appears to involve the forming of a peripheral layer of bacteroids under the membrane of young egg cells. Other methods of transmission may be by contamination of the eggs as they pass through the genital canal of the female, whereupon feeding on the egg cases will cause reinfection, and by seminal transfer. In other cases, bacteroids may occur in the cells of the gut wall and be set free in the gut cavity, as in some insects of the family Cerambycidae, or may be confined to special cells, "mycetocytes" grouped to form a mycetome in the intestinal wall (*14*). Culture of these microorganisms has been claimed (*15*), but the techniques have met with criticism and are not universally accepted (*14*). Hence, the presence or absence of intracellular symbionts has been successfully ascertained only when staining procedures have been used (*13*).

The staining methods of Brooks and Richards were used on 10-micron sections of silverfish. Additional stains were used, including Gram's, van Gieson's, and Safranin and Fast Green. No mycetomes, mycetocytes, or other structures similar in nature were ever observed in the silverfish. The fat body was completely free of these structures, as were the cells of the crop and the midgut, the glandular portion of the intestine. From these observations, it seems reasonable to conclude that intracellular microorganisms are not a factor in the digestive processes of the silverfish, *C. lineata*.

The evidence up to this point shows that the silverfish can digest cellulose and that this cannot be the result of a symbiotic microflora or -fauna in the animal's intestine. However, more conclusive evidence would be a demonstration of the digestibility of cellulose by silverfish that have been completely deprived of contaminating bacteria. This was accomplished by sterilizing the eggs (Fig. 2) of the animal in a solution containing mercuric chloride and ethanol. Tests in a nutrient medium of whole eggs, crushed eggs, nymphs, or scaled juveniles showed that in no case were bacteria present after this treatment. When these nymphs were fed radioactive cellulose, their respiratory carbon became highly radioactive. When bacteria-free nymphs were fed a mixed diet containing rolled oat and radioactive cellulose, the carbon

Fig 2. An egg, a newly hatched nymph, and an emerging nymph of the silverfish *C. lineata*. The egg is 1 millimeter long.

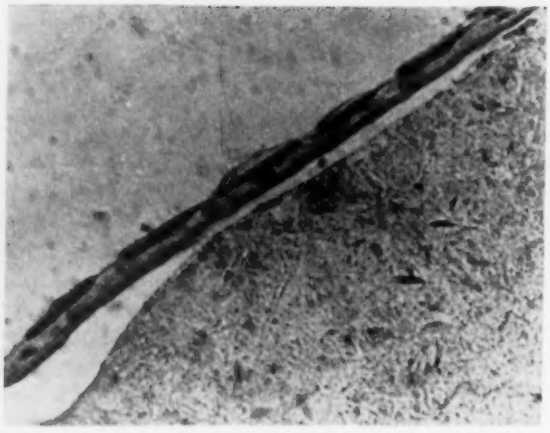


Fig. 3. Crop wall of *C. lineata*. The crop appears to be one cell in thickness. Circular muscle bands alternate along its length (longitudinal section).

dioxide evolved also contained radioactive carbon but to a lesser extent. This indicated that, given a mixed diet containing cellulose, the silverfish will not exclude cellulose from its diet even when a digestible nitrogen source is available.

Role of Cellulolytic Enzymes

It is now clear that *C. lineata*, a typical paper-eating silverfish, is able to digest cellulose with great efficiency and without the aid of intestinal symbiotic microorganisms. To explain this fact, the animal should produce in its own tissues an organic catalyst or enzyme (cellulase) whose function would be to mediate the breakdown of cellulose. The crop is essentially a single layer of cells with thin muscle layers (Fig. 3). The midgut, by contrast, is glandular and has many secretory cells (Fig. 4). This leads one to believe that digestive enzymes may be elaborated in the midgut. Later in the investigation, an active cellulase was found in cell-free extracts of the silverfish midgut. The extracts were found to be effective on both cellulose and cellobiose, a disaccharide of glucose similar to cellulose. Optimal values of *p*H for the cellobiase ranged between 4.5 and 5.0 and around 6.1; for cellulase, optima were at *p*H 4.0 and 6.0. A very efficient starch-splitting enzyme, amylase, was also present in the midgut. It was possible to further isolate and purify the cellulase from silverfish midguts by ammonium sulfate fractionation. A preparation was then obtained which was 3 to 4 times as active as the original cell-free extracts (*6*).

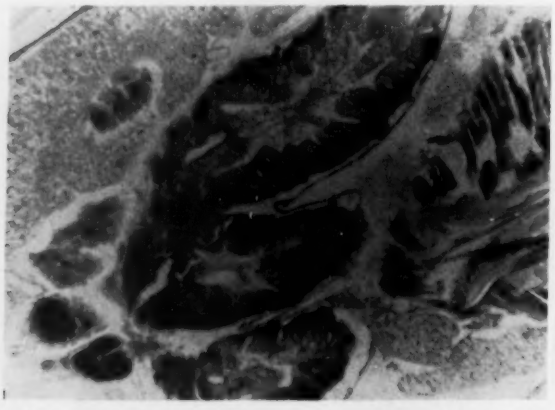


Fig. 4. Midgut of *C. lineata*. The midgut is typically glandular and is probably the source of the digestive enzymes. To the right of the midgut are seen the muscles of the gizzard.

On the basis of the results discussed here and in other published work, it is now possible to present a more complete account of the biology of a silverfish. *Ctenolepisma lineata* has a simple intestinal tract consisting of a short esophagus, a large crop, a gizzard, a midgut with 11 relatively large glandular pockets which make up the main body of the organ, a hindgut, and a rectum. A large pair of salivary glands enters the esophagus. The crop is thin-walled and usually holds food for extended periods. Considering the simple nature of the crop wall, it is probably only a storage organ, and it is unlikely that digestive enzymes are produced there. Experiments carried out with other insects (*16*) seem to indicate that the crop does not serve an absorptive function, and there is no evidence one way or the other for this in the silverfish. In freshly dissected animals, occasionally the crop was full of a solid recognizable food (for example, insect remains). None of these materials was ever seen past the gizzard despite the bulging of the crop wall because of the unusual quantity of food eaten. On other occasions, the crop contents were semi-solid or completely liquid. Presumably food is digested in the crop.

The midgut never appears to have solid food in it, but sometimes it is filled with a brownish fluid. From the results of the experiments reported here, the midgut appears to be a rich source of enzymes for the silverfish. The enzymes may be pumped forward to the crop as in some insects in the order Orthoptera (*16*); the gizzard probably acts to retain small particles, preventing them from entering the midgut, while digestive juices pass through it. The teeth of the gizzard are well-developed in this animal, and it is more than likely that grinding is also one of its functions.

Fecal pellets are produced just posterior to the main body of the midgut and can be correlated

with the insertion of the Malpighian tubules, ducts for nitrogen waste products. The fecal pellets are essentially dry since the rectum efficiently removes all the water (*17*). Since this animal ingests no water except that found in its food, the adaptive value of this efficient water-absorbing mechanism is evident.

A number of enzymes are produced by the midgut of the animal. It is clear that the silverfish can readily utilize the complex polysaccharide, cellulose, by hydrolyzing it with its own enzymes. A cellulase is produced in the midgut, where a cellobiase and amylase are also elaborated.

Effect on Nitrogen Utilization

Since the silverfish is an avid consumer of materials that are high in carbohydrate content, and since the nitrogen content of these foods may be very low, it was also of interest to ascertain whether or not the animal could conserve its nitrogen when it was feeding on an essentially nitrogen-free diet.

When silverfish are fed pure filter-paper cellulose for several months, feces production is slight. If a rich nitrogen source is then fed, a great increase in feces production occurs. The nitrogen content per unit weight of fecal materials under both conditions is almost identical. When fed a digestible carbohydrate lacking nitrogen, like cellulose, silverfish do not excrete nitrogen to any great extent. When starved for nitrogen, the animal will conserve what nitrogen it has simply by excreting less.

The conversion efficiency of nitrogen to tissue is high in this insect. Normally, the milligrams of nitrogen required to give 1 milligram of animal wet weight ranges from 0.03 to 0.13. If an animal has been feeding on cellulose exclusively and is then switched to a rich nitrogen diet, its conversion efficiency is abnormally high (0.014 in a typical case). After a 2-week period, this efficiency drops to a more normal level (0.037) (*5*).

The high carbohydrate content of the diet of *C. lineata* must be accompanied by sources of digestible nitrogenous material, although the animal is still capable of surviving for a considerable period of time on a diet low in, or devoid of, utilizable nitrogen. However, the animal seems to need a good nitrogenous food within a few weeks, or it will not survive.

References and Notes

1. R. Hooke, *Micrographia or some Physiological Descriptions of Minute Bodies made by magnifying glasses with observations and inquiries thereupon* (London, 1665).
2. H. Garman, *U.S. Dept. Agr. Entomol. Bull.* **60**, 174 (1906); A. Mallis, *J. Econ. Entomol.* **34**, 787 (1941); Y. Yamadi, *Botyu-Kagaku* No. 7/9, 33 (1947).
3. E. Lindsay, *Proc. Roy. Soc. Victoria* (N.S.) **52**, 35 (1940).
4. This investigation was aided by a predoctoral U.S. Public Health Service research fellowship that I held during 1955.
5. R. Lasker, doctoral dissertation, Stanford University (1956).
6. ———and A. C. Giese, *J. Exptl. Biol.* **33**, 533 (1956).
7. K. D. Roeder, Ed., *Insect Physiology* (Wiley, New York, 1953).
8. L. A. Maynard, *Animal Nutrition* (McGraw-Hill, New York, 1937).
9. R. E. Hungate, *Bacteriol. Revs.* **14**, 1 (1950); L. R. Cleveland, *Biol. Bull.* **46**, 178 (1924).
10. J. F. Wiedemann, *Z. wiss. Biol. Abt. A. Z. Morphol. Ökol. Tiere* **19**, 228 (1930).
11. E. Lindsay, *Proc. Roy. Soc. Victoria* (N.S.) **51**, 99 (1939); J. W. Cornwall, *Indian J. Med. Research* **3**, 116 (1915).
12. P. Buchner, *Endosymbiose der Tiere mit pflanzlichen Microorganismen* (Birkhäuser, Basel, 1953).
13. M. A. Brooks and A. G. Richards, *Biol. Bull.* **109**, 22 (1955).
14. E. A. Steinhaus, *Principles of Insect Pathology* (McGraw-Hill, New York, 1949).
15. R. W. Glaser, *J. Exptl. Med.* **51**, 59 (1930).
16. V. B. Wigglesworth, *The Principles of Insect Physiology* (Methuen, London, 1950).
17. ———*Quart. J. Microscop. Sci.* **75**, 131 (1932).

Jungle Brimstone

WILLIAMS HAYNES

Mr. Haynes, formerly publisher of Chemical Industries, *was trained in economics and chemistry at Johns Hopkins University. Since his retirement he has devoted himself to consulting and writing. Among his books are the six-volume history,* American Chemical Industry; *a textbook,* Chemical Economics; The Stone That Burns; Men, Money and Molecules; Cellulose; *and* This Chemical Age.

CHRISTMAS Eve, 1894, on a 75-acre oasis of dry ground in the midst of a Louisiana swamp, a bold experiment was carried out in a 10-inch test tube 623 feet long. Its failure had been flatly foretold by all the experts. It could not be tested in laboratory or pilot plant: it had to be a gigantic gamble.

By piping superheated water down to a stratum of porous limestone impregnated with sulfur, Herman Frasch hoped to melt the yellow mineral and pump it to the surface in molten form. It seemed a fantastic idea, and Frasch himself did not appear to be the man for such a job—he was a stubby little chemist with a vandyke beard and beribboned eyeglasses, the popular idea of an ivory-tower scientist. Frasch was, however, venturesome and persistent, an experienced, resourceful engineer, and a shrewd businessman—and he was lucky.

His hot-water method of mining worked in theory. It did bring to the surface a molasses-colored liquid that solidified in minutes into sparkling bright yellow brimstone, better than 99.5 percent pure elemental sulfur. In practice, however, the Frasch process balked and kicked like an evil-tempered mule (*1*).

Time after time, overstrain and corrosion snapped the sucker rod of the pumps. The sulfur froze in the pipe, which had to be pulled, disjointed, and over 400 feet chipped clean with cold chisels. In some wells the hot water drained away ineffectively through fissures. In others, where the limestone structure was exceptionally tight, the water backed up, and bleed wells had to be bored to draw it off. When the sulfur melted out, the limestone collapsed, creating a new set of problems. Working blindfolded, 600 feet underground, it took the tenacious Frasch 6 years to achieve consistent operation. It was lucky that the sulfur-bearing formation which he hit was regular and comparatively easy to work. Otherwise the Frasch process might never have been perfected.

Having learned how to bring up sulfur efficiently, Frasch then discovered that he could not sell it profitably. By a lucky coincidence, in 1901, when the kinks had all been ironed out of his process, the fabulous Spindletop oil gusher was struck only 30 miles away (*2*). In hot-water mining, the prime necessity is millions of gallons of water; the prime cost factor, the price of fuel. In the early operations, it required more than 4000 gallons of water heated to 230°F to raise a ton of sulfur. The cheapest available fuel, soft coal from Alabama delivered in Louisiana at $4.05 a ton, did not enable Frasch to compete on a cost basis with sulfur from Sicily (*3*). Since the days of Imperial Rome, Sicilian sulfur, dug with pick and shovel and crudely refined in kilnlike furnaces, had been the world's chief source of supply.

Fuel oil piped from Spindletop at 60 cents a barrel, delivered, saved the hot-water process. Its repercussions have been world-wide, and they touch each one of us. Sulfur is the key element in sulfuric acid, and in every manufactured article we use from paper clips to Diesel engines, from a sheet of paper to a suit of clothes, sulfuric acid is always the "invisible ingredient."

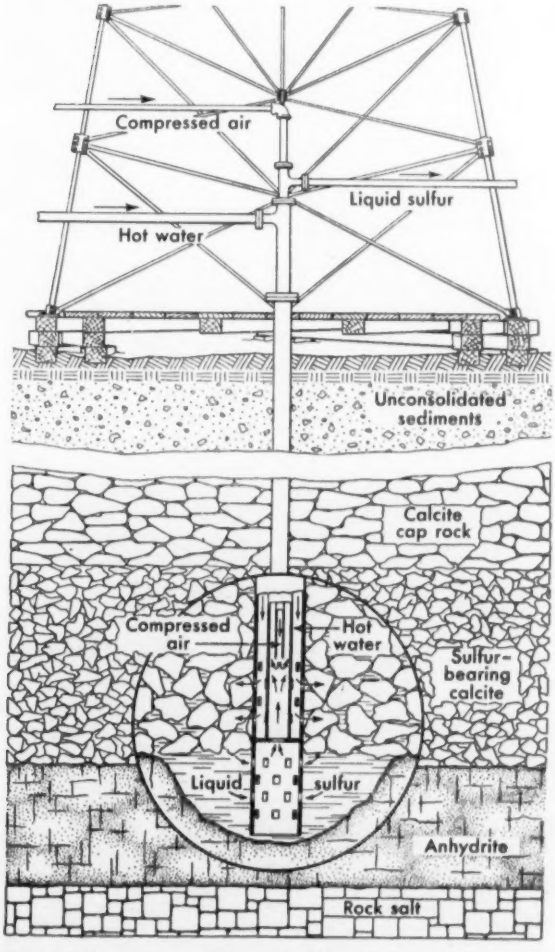
During the past half century, the ingenious Frasch process has brought to the surface 100 million tons of pure sulfur which otherwise would have remained buried underground, useless. It has reduced the cost of this vital chemical commodity by 40 percent. Today it produces four-fifths of the world's brimstone. It has created a distinctively U.S. industry which, after 30 years of supremacy in the international market, now faces a competent competitor, sulfur from the jungles of southern Mexico.

The control of the brimstone market enjoyed by the four American companies operating in Texas and Louisiana has been based, not on patents or cartel agreements or a trust, but on a God-given monopoly. Sulfur can only be mined by the Frasch process from a particular geologic formation, the sulfur-bearing caprock of a salt dome. Such domes are found only in the coastal plain bordering the Gulf of Mexico (*4*).

Origin of Salt Domes

From the delta of the Mississippi to the peninsula of Yucatan, the whole coastal region lies over a thick bed of salt which was evaporated out of a vast sea in the hot and humid days of the dinosaurs. During the past 115 million years, this salt has been buried some 20,000 feet under sedimentary deposits: clays, sands, and shales, and less frequently gravel and volcanic ash.

Under the static pressure of the weight of these overlying sediments, the salt becomes plastic and it flows. This phenomenon has been actually observed in Iran. From the base of salt-cored mountains, salt flows down into the valley, a veritable salt glacier (*5*). Throughout the Gulf Coast region, this dynamic pressure, upthrusting the salt from the mother bed beneath, and the static pressure of the overlying material have combined to create distinctive salt domes. Friction and gravity compress the salt rising through the sediments into the form of gigantic pillars topped with a caprock of limestone. DeGolyer has graphically pictured these strange structures as billiard cues of salt tipped with limestone.



Frasch hot-water operation, showing the arrangements of pipes above ground and in the sulfur-bearing structure. [From E. C. Weaver and L. S. Foster, *Chemistry for Our Times,* McGraw-Hill Book Company; adapted from Texas Gulf Sulphur]

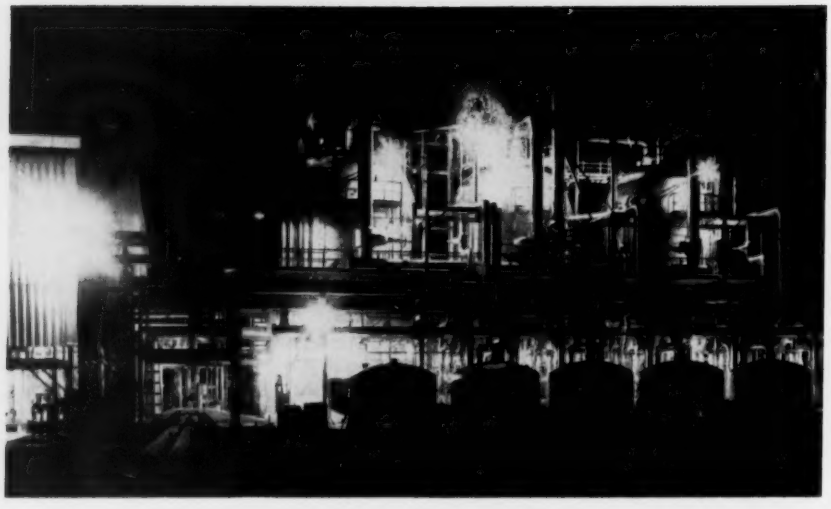
Although similar in form, the salt domes differ greatly in detail. Their tops vary in area from an acre or so to a couple of square miles. Some have risen to within 100 feet of the surface. Others have been located by geophysical methods at depths greater than 2000 feet. As they approach the surface, the domes have pushed up conspicuous mounds, distinguishing and characteristic landmarks of the flat coastal plains.

Like the domes, the caprocks display great variety. They differ in size and shape, in depth and internal structure. Again the general pattern is well fixed. First comes a layer of limestone, barren of sulfur, but containing anhydrite (anhydrous calcium sulfate) and gypsum (hydrous calcium sulfate). Beneath this lies a stratum of limestone of various thickness and continuity whose fissures, cracks, and seams may be—or may not be—impregnated with pure native sulfur. Beneath the sulfur-bearing stratum is a layer of anhydrite covering the salt core of the dome itself.

Similar salt domes have been found in Colorado and Utah, in Germany, Rumania, and Iran. But only those bordering the Gulf of Mexico are topped with a limestone cap containing sulfur. Geologists quite promptly agreed upon the origin and formation of these curious structures, but chemists still debate several theories to explain how the sulfur got into the caprock.

Wildcatting in Mexico

The Rio Grande River, geologically speaking, is but a scratch on the surface of the Gulf Coast, and in 1902 an oil drilling crew, imported from Texas by the English petroleum company, El Aguila (the Eagle), struck the sulfur-bearing caprock of a salt dome down in the Isthmus of Tehuantepec. Here Mexico narrows to a mere 150 miles and swings toward the east so that, paradoxically, the Gulf of Mexico lies due north of the Pacific Ocean. When that wildcatting crew struck that caprock they knocked off work for a celebration of historic dimensions. They were not impressed with the sulfur. But every man knew that the year before, near Beaumont, Texas, the incredible Spindletop gusher



A Frasch sulfur plant operates on a 24-hour schedule. In the foreground are the water purification units; behind them are the large heaters.

had been struck along the salt flanks of just such a dome.

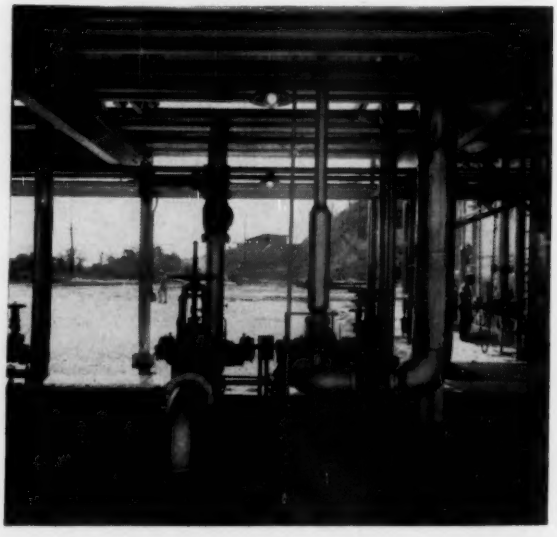
Almost before that 200-foot fountain of oil had been brought under control, its discoverer, Anthony Lucas, set off "to punch a hole in every pimple on the Gulf Coast." Guided by the same obvious, tempting analogy, the English interests in the isthmus sent out scouts to locate every mound in the swampy jungle. Following them, drilling crews slashed roadways through snarls of creepers as brutally barbed as our bullbriars and dragged in the heavy rigs. They opened up Mexico's first oil field and found some 40 salt domes whose caprocks showed more or less sulfur (*6*).

The oilmen were simply not interested in sulfur. Thirty-five years later, Frederico Deschamps read a paper before the Mexican Geological Society berating the petroleum companies for neglecting the economic importance of the deposits in the isthmus (*7*). Deschamps was flogging a dead horse. As a matter of plain commercial fact, in 1937 the Mexican sulfur deposits were of no "economic importance" whatsoever.

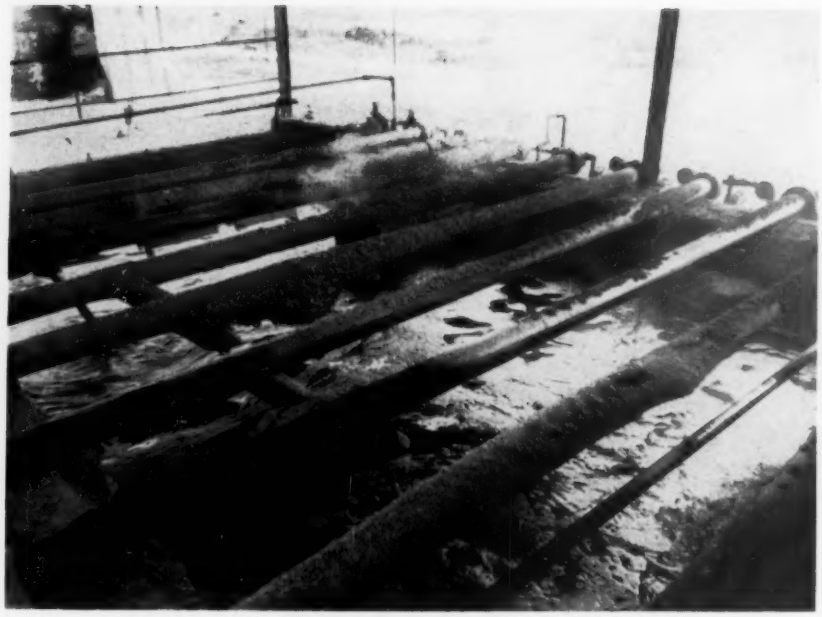
From domes in Texas and Louisiana more than enough pure sulfur was being pumped to supply all the world's demands. Production that year totaled 2,741,970 long tons; shipments were 2,466,512 tons (*8*, p. 313). Moreover, huge blocks of yellow brimstone, nearly 2 million tons of it, stood above ground; a stockpile sufficient for 10 months' supply (*8*, p. 315).

In 1938, when Mexico expropriated its oil industry, three Texans, Lawrence, William, and Ashton Brady, brothers, were wildcatting just across the Rio Grande. Their venture was thus abruptly stopped, so they began hunting other opportunities in the Republic. Being ignorant of pick-and-shovel mining and experienced in drilling, when they learned of the salt-dome sulfur found 40 years before, they were immediately charmed by this gambling prospect. Accordingly, while William, the diplomat, and Lawrence, the legally trained leader of the trio, undertook to secure a sulfur-exploring concession from the Government, Ashton, a geologist, went to the library of the Mexican Geological Institute. In old technical and trade journals he found news stories of the Tehuantepec explorations, reports from oil scouts, scientific papers by geologists, even maps and drilling logs.

In the spring of 1944, the Bradys freighted down their drilling rig and barged it up the Coachapan



Pumping station at Salinas. In the background, the offices and cafeteria are being built.



The sump where the molten sulfur is collected from the individual mine pipes before being vatted to cool or pumped to heated tanks for shipping in liquefied form.

River to a little native village, San Cristóbal, 25 miles from the free port of Coatzacoalcos on the Gulf of Mexico. Near here, alongside a sulfur-bearing salt dome, was the "discovery well" of all Mexico. The field had been thoroughly exploited. But when the Eagle drillers had struck sulfur and no oil, they economically pulled their pipe and moved on. Accordingly, although many logs recorded brimstone, the location of these holes was unmarked.

Hunting Sulfur in the Jungle

Ashton Brady hired an invaluable guide, the headman of San Cristóbal, Julio Blanco, who had worked for the Eagle. Amid a tangle of tropical underbrush, he led Brady to the capped iron pipe that marked the historic well. Brady paced off a point where he calculated he stood 745 feet above a rich sulfur deposit (*9*). Over a fresh-cut jungle road, working in the downpour of the rainy season, they inched the top-heavy rig a mile and a half to location and spudded in.

After a long series of frustrating breakdowns and delays, they reached the caprock in mid-September—5 months for a job they had estimated would take 6 weeks and which under normal conditions could now be done in 5 days. The showing of sulfur was microscopic. Brady pulled his drill and dragged the rig 1000 yards to another likely location. Two months later he hit an even more barren spot in the caprock.

The first "dry hole" prompted half the friends who had joined the Bradys in this sulfur gamble to withdraw; the others now abandoned this venture. However, Ashton Brady was now certain that he knew just where sulfur had been found, and his brothers scratched together $16,000 for a final try. He reached a rich showing of sulfur. They organized the Mexican Gulf Sulphur Company, and Lawrence Brady went to New York to raise the $5,000,000 needed to build a Frasch plant at San Cristóbal. Most of the "Mexsulf" stock was sold in Dallas and Houston, where a sweepstakes ticket is considered a better investment than a Government bond. Here, too, half a dozen alert, wealthy oilmen, led by J. R. Parten, became interested in Mexican sulfur. In exchange for an option on the Bradys' concession at Jáltipan, they sent down a modern drill and underwrote the preliminary exploration of this property.

Again Ashton Brady was fortunate in finding at Jáltipan a veteran of the oil days, and with a twisted, rusty piece of cable and a broken length of pipe for clues, they struck sulfur in the first well. The Parten group took over and, after drilling more than 100 wells to outline the structure and estimate the reserves, organized the Pan American Sulphur Company (*10*).

Threatening Shortage

At this juncture, an unexpected sulfur shortage focused attention on a new source of supply in Mexico. Frasch sulfur had filled the war's extraordinary demands, but these had cut down our pre-

Loading a French ship at Coatzacoalcos, a Mexican free port with an excellent harbor and large docks. Coatzacoalcos is enjoying a revival of the days before the opening of the Panama Canal, when it was one of the busiest seaports on the Gulf of Mexico.

war stockpile of 4.4 million tons to 3.5 in 1945. Instead of the expected postwar industrial slump, a great world-wide expansion of chemical activity further reduced that stockpile to 2.5 million tons by 1950 (*11*). Despite a 38 percent increase in output above the World War II peak, American producers were unable to catch up with growing world demands increased by the Korean conflict. The chemical community suddenly realized that American reserves of salt-dome sulfur are not unlimited. Our entire Gulf Coast region has been punched like a pincushion. Except offshore, where operations are more costly, there is little prospect of finding new domes. Overnight, Mexican sulfur became exceedingly interesting. Concerned over our domestic reserves, the Export-Import Bank made loans to provide for completion of the plants at San Cristóbal and Jáltipan.

Meanwhile, down on the isthmus, Ashton Brady had returned to San Cristóbal. He moved his battered rig back to the river, built a raft, and poled it across to Salinas on the opposite bank. Here, too, he found sulfur, and a third company, Gulf Sulphur of Mexico, was launched. Almost simultaneously with the first production at Salinas, last May, the Brady brothers sold their stock in all three companies, resigning their directorships but retaining their royalty interest in these enterprises (*12*).

Outside the Brady orbit, Texas Gulf Sulphur, the largest American producer, has entered the Mexican field. They built their plant, not on location, but at Houston, and have barged it across the gulf and up the Coachapan River to their concession at Nopalapam, just above Salinas and San Cristóbal (*13*). Two other companies, Texas International and Isthmus Sulphur, have concessions and are exploring. The former has announced financial arrangements that will enable it to build a plant. (*14*).

This 2-year-old Mexican industry will produce this year close to 1 million tons of sulfur. Any prediction of 1957 output should be made with cautious reservations, but 1.5 million tons is a conservative guess (*15*). This tonnage approaches a third of the U.S. production and is more than 15 times Mexico's domestic consumption.

Industry's Invisible Ingredient

Nine-tenths of all the sulfur produced is used in making sulfuric acid, "the old war horse of chemistry," so universally employed in manufacturing processes that its consumption is the most reliable barometer of a nation's industrial activity. The maker of sulfuric acid, H_2SO_4, takes hydrogen from water and oxygen from the air, but he must buy sulfur in some form. This essential ingredient can be roasted out of pyrites (iron sulfides); snatched from waste smelter gases at metal refineries; or extracted chemically from natural gas and crude petroleum. Impure sulfur is also scraped

out of the craters of dead volcanos and dug from surface deposits all over the globe. But the acid-maker's cheapest, most convenient source of sulfur is pure Frasch sulfur, and the so-called contact process is his most economical and simple method of producing acid of the highest strength and purity.

Since World War I, a basic trend in chemical technology has been the switch from pyrites to the contact process fed by brimstone. Therefore, during the sulfur shortage of 1950–51, allocations to domestic consumers and cut-backs of our exports (*16*) deeply concerned sulfuric acid makers the world around and stimulated revived interest in other sources of this chemical element (*17*).

Thus the Mexican sulfur industry makes its debut at a crucial time and in an ironical double role. An American process, operated in American-designed plants by American know-how, financed by dollars (many of them American taxpayers' dollars loaned by the Export-Import Bank) has created a competitor for a distinctively American industry. Contrariwise, this new competitor may well rescue the Frasch process from economic obsolescence. If the supply of salt-dome sulfur falters or its price advances markedly, several substitute sources of the element and alternate processes of acid manufacture are ready to take its place. Foreign buyers have welcomed this second source of sulfur, and by taking over a share of our mounting exports, Mexican sulfur will not only conserve our reserves, but also strengthen brimstone's historic position in the chemical marketplace.

Looking ahead—plainly there is much sulfur in the Isthmus of Tehuantepec, and it can be mined economically by the Frasch process. Proven reserves on the three original companies' concessions —and these represent the exploration of only 1319 out of 32,078 acres—are in excess of 50 million tons (*18*). The surface has only been scratched even in the 2.5 million acres set aside by the Mexican Government as a sulfur reserve in the State of Veracruz. Sulfur has been located in neighboring Tabasco, and geologic logic suggests that the salt domes may extend into Chiapas and Yucatan.

Health and Welfare Benefits

The first beneficiaries of this new industry have been the people of the Isthmus of Tehuantepec: hundreds of jobs at higher wages than the Mexican minimum, improved roads (*19*), and new schools, infirmaries, and sanitary systems, the last three installed in whole or in part by the sulfur companies. The impact on the primitive life of this remote region has been stunning. Mexican doctors and nurses on the staffs of the companies are fast freeing this jungleland of its ancient scourges, malaria, typhoid, and dysentery. Concrete cottages with tile roofs are replacing bamboo huts thatched with palm leaves. A parked car no longer gathers a gaping audience. Each village still has its old market where home-woven cottons and home-made rawhide sandals with automobile tire soles are bartered for pottery and baskets, corn and beans, but now miniature supermarkets sell such amazing items as nylon stockings and sport shirts, nails and hammers, canned salmon and peaches. And—the acid test of civilization—the women now wear blouses above their long, graceful wrap-around skirts.

All Mexico has a big stake in sulfur. On top of the government's royalty on every ton of brimstone surfaced and its sales and export taxes, all the plants are fueled by oil bought from the petroleum monopoly, Pemex, and the sulfur mined at Jáltipan is freighted to Coatzacoalcos by the government-owned railway. That little port is luxuriating in a boom. A large, newly found natural gas field in Tabasco is to be joined to the Pemex refinery at Minatitlán by a 50-mile pipe line. It will give the sulfur companies a cheaper, more easily handled, more efficient fuel. But if this big industrial consumer were not at hand, this ambitious, costly engineering project could not be undertaken; this additional national resource could not be employed economically; this wild, primitive region would not be opened up.

More broadly considered, Mexico now has a big domestic source of pure sulfur, and already two new acid plants are being built and two others are planned—plants that will stoutly support the country's expanding industrialization. Finally, Mexico now has a sizable exportable surplus of an essential chemical commodity in world-wide demand with which to strengthen her international balances.

References and Notes

1. The best first-hand sources on early operation of the hot-water process are Frasch's acceptance speech of the Perkin Medal, New York, 12 Jan. 1913, [*J. Ind. Eng. Chem.* **4**, 138 (1913); *Chem. Met. Eng.* **10**, 78 (1913)] and the testimony of J. Toinette, J. C. Hoffman, A. F. Lucas, and A. Webber in the suit over the Frasch patents (U.S. patents 461,429 and 461,430) *Union Sulphur Co. vs Freeport Texas Co., U.S. Circuit Court of Appeals, 3rd Circuit*, I, 358–91, 487–535, 536–49; II, 776–867; see also D. A. Willey, *Eng. Mining J.* **84**, 1107 (1908); W. Haynes, *The Stone That Burns* (Van Nostrand, New York, 1942) pp. 3–6, 24–45.
2. C. A. Warner, *Texas Oil and Gas Since 1543* (Gulf Publishing, Houston, Tex., 1939), pp. 37–48; *Texas Almanac, 1939–40*, 215–18; M. W. Ball, *This Fasci-*

nating Oil Business (Bobbs-Merrill, Indianapolis, 1940), pp. 354–56.

3. *Union Sulphur Co. vs Freeport Texas Co., U.S. Circuit Court of Appeals, 3rd Circuit,* I, 564; W. Haynes, *The Stone That Burns* (Van Nostrand, New York, 1942), pp. 68–70.
4. In this enormous technical literature two of the best general descriptions of the salt domes are G. D. Harris, *Geol. Survey Louisiana Bull. No. 7* (1917) and *U.S. Geol. Survey Bull. No. 429* (1910); especially useful are C. W. Hayes and W. Kennedy, *U.S. Geol. Survey Bull. No. 212* (1913); E. de Golyer, in *Geology of the Salt Dome Oil Fields*, R. C. Moore, Ed., pp. 1–44; G. S. Rogers, *Econ. Geol.* **13**, 468 (1918); A. G. Wolf, *Mining Eng. J.* **115**, 412 (1923); F. M. Van Tuyl, *Bull. Am. Assoc. Petroleum Geol.* **14**, 1041 (1930); D. C. Barton, *Bull. Am. Assoc. Petroleum Geol.* **17**, 1025 (1933); M. A. Hanna, *Bull. Am. Assoc. Petroleum Geol.* **18**, 629 (1934); L. L. Nettleton, *Bull. Am. Assoc. Petroleum Geol.* **18**, 1175 (1934); popular description, *J. Chem. Educ.* **12**, 19 (1935).
5. J. V. Harrison, *J. Inst. Petroleum Geol.* **17**, 300 (1931).
6. Sir Weetman Pearson (later Lord Cowdray) had an oil concession from President Porfirio Diaz for the entire Gulf Coast region of the Isthmus of Tehuantepec, and here in 1902 his Cia. Mexicana de Petroleo el Aguila, S.A. (the Mexican Eagle Petroleum Co., Inc.) brought in the first commercial production of oil in Mexico. Aguila later became the nucleus of the Royal Dutch-Shell interests in Mexico. For early exploration of the isthmus domes and their geology, see A. Barroso, *Anal. Minist. de Fomento Rep. Mex.* **3**, 273 (1897); M. Alcala, *Mem. Soc. Cieritifica Antonio Alzate* **13**, 311 (1900) abst. *Mining Mag.* **81**, 88 (1905); J. D. Villarello, *Inst. Geol. Mex. Bol. No. 26* (1908) abst. *Mining Mag.* **85**, 609 (1909); F. W. Moon, *Trans. Inst. Mining Metal.* (*London*) **20**, 250 (1910); E. de Golyer, *Trans. Am. Inst. Mining Met. Engrs.* **61**, 456 (1919); S. Huntley, *Trans. Am. Inst. Mining Met. Engrs.* **69**, 1150 (1923); L. J. Lajous, *Bol. Petroleo* **18**, 150 (1922); W. A. Ver Wiebe, *Panamanian Geologist* **44**, 121 (1925); **45**, 358 (1926).
7. F. Deschamps, *Revista Mex. Ingen. y Arquit.* **15**, 665, 777 (1936).
8. W. Haynes, *The Stone That Burns* (Van Nostrand, New York, 1942).
9. The account of exploring, financing, and developing Mexican deposits is based on interviews with the Brady brothers, Alfonso Barnetche, C. L. Basland, Alfredo Breceda, L. N. J. Creel, E. de Auzorena, R. M. de Escobar, S. C. Dorman, J. H. Kearney, E. O. Mason, J. F. Patten, R. B. Roberson, David Segura, and Ectuardo Suarez in Mexico City; with C. E. Armstrong, W. P. Barnard, J. B. Brannam, H. H. Jacquet, W. H. Maddox, Richard Mills, S. M. Richards, Eugene Rossi, R. M. Stoy, and Jas. Woodburn at operations in the isthmus; and with Claude Crockett, M. J. Davis, J. B. Eby, H. W. Haines, Jr., Douglas Johnson, R. H. Johnson, M. A. S. Markris, G. R. Marlow, Dwight Morrow, J. H. Pollard, Paul Weaver, and H. C. Webb at Houston, Tex.
10. J. H. Kearney, *Eng. Mining J.* Jan. 1955, 72.
11. W. T. Lundy, *Ind. Eng. Chem.* **42**, 2199 (1950); J. C. Carrington, *Mining Congr. J.* **37**, 53 (1951); *Chem. Eng.* **59**, 165 (1952); popular resumé, *Fortune* **44**, 87 (1951).
12. *Chem. Eng. News* **34**, 2412 (1956).
13. *Ibid.* **34**, 3079 (1956).
14. *Business Week* 64 (18 Sept. 1954); *Chem. Eng. News* **34**, 4082 (1956).
15. *Chem. Eng. News* **34**, 4530 (1956).
16. *U.S. State Dept. Bull. No. 25,* 194, 711 (1951); *No. 28,* 119 (1953).
17. *Economist* (*London*) 910 (25 Nov. 1950); 1250 (25 May 1951); W. A. Parks, *Chem. Age* (*London*) 679 (28 Apr. 1951); A. Fleck, *Chem. and Ind.* (*London*) 1184 (6 Dec. 1952).
18. Lic. Jose Campilló, *Memo. on Sulphur* to Ing. Marte R. Gómez, Mexico City (26 Apr. 1956)—an official report from the secretary, Mining Chamber of Mexico, to the president of the Comision de Formento Minero, the bureau controlling the sulfur reserve set aside in the Isthmus of Tehuantepec. It is pertinent that of this reserve of roughly 2.5 million acres, only 182,000 acres are now under either mining contract or exploring concession.
19. Beyond the paving of local highways and the building of roads by various companies, the Mexican Government has recently opened a highway across the Isthmus of Tehuantepec from Coatzacoalcos to the Pacific port of Salinas Cruz and has started construction of a new road through the State of Tabasco to Campeche, a difficult engineering project through swamps and across nine big rivers.

Scientists through Adolescent Eyes: What We Need To Know, Why We Need To Know It

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WHENEVER the problem of the shortage of scientists is examined, it is generally asserted that a crucial factor pertaining to the solution of the shortage is the possibility of motivating sufficient numbers of bright high-school students to plan careers as scientists.

In the following paragraphs, I hope to point out certain requirements that are necessary for an adequate appraisal of the nature and magnitude of the motivation problem which, to my mind, have been overlooked or for which answers appear to have been rather gratuitously assumed. Further, I hope to indicate what means could be used to attain the necessary information for understanding the problem and perhaps the means for indicating along which lines ameliorative activities might be undertaken.

This article (*1*) will neither argue nor discuss the problems of whether or not there is a shortage of scientific manpower, whether or not the scientist and science as a career deserve preferential treatment in our institutions and our culture, and whether or not the future of democracy and a healthy economy are primarily dependent on an expanding supply of first-rate scientists. I shall simply assume the popular position that if we want more scientists, we must succeed in motivating more first-rate high-school students to become scientists.

Motivation and Stereotypes

Some months ago a furor arose—and quickly died—over the expressions of disdain which Melvin Barnes, assistant superintendent of Oklahoma City schools, elicited from a few students in response to an informal and ad hoc questionnaire on why students do not study science and mathematics (*2*). And very recently H. H. Remmers has reported his findings from a large sample of high-school students (*3*), indicating that many of them do not hold scientists and science in high esteem. Yet it is disturbing to note that while all who are concerned about a shortage of scientists give lip service to the motivation problem, there has not been, to my knowledge, any clear call emphasizing the need for systematic studies aimed at ascertaining the stereotypes, and the values underlying them, that students hold about the rewards and disadvantages of careers in general compared with the career of the scientist in particular. Why such studies especially?

At the risk of laboring the obvious, I will briefly review the relationship between motivation and stereotypes. Among those factors contributing to the direction and intensity of behavior, certainly a crucial one is the perceived consequences of pursuing and reaching a specified goal. There is abundant evidence that these perceived consequences are almost never evaluated in an exclusively objective and individualistic way; the goals are perceived and evaluated in a context of the values of the culture in which the person participates. But since people often have no experience before the fact upon which to make first-hand appraisals of the consequences of their behavior, they frequently use instead stereotyped knowledge about what an unexperienced situation will be like—and they evaluate that situation and select their goals in terms of the values their culture assigns to such aspirations and the way of life pertaining thereto (*4*).

Stereotyping is, of course, not in itself bad, but

it can be, and for most of us under many circumstances is, a serious detriment to realistic evaluations of situations. Since high-school students have not been scientists—or much of any other type of worker for that matter—their picture of the various ways of life must come to them through the stereotypes presented by both the formal and informal educative processes to which they are exposed. If the values of this society tend to be away from the values popularly perceived as associated with the scientist, the stereotypes comprising some students' picture of a life of science may well be distorted enough to deflect them from such a life, especially if they see it as conflicting with the values they subscribe to and with other stereotypes which they may believe about the way of life they anticipate living.

There are good psychological and sociological reasons—to say nothing of first-hand, personal experience of many observers of the American scene, including foreign scientists—for believing that the whole trend of our society, the values of our society, are in fact away from the contemplative, away from respect for and concern with the complex, away from a sense of calling, of dedication, of single-minded purpose. Not only is the trend away from these values, which were associated with an earlier period in our society—and still are associated with the cultures of much of the rest of the world—but there seem to be clear evidences of a downright negative attitude toward such a way of life as is associated with the "egghead" and the "longhair."

Of course, it may well be that not only is this the case but that there is nothing we can do about it. If this is granted, then clearly any efforts to motivate students to take up the scientific way of life are, in the long run, futile. But if there is something that can be done about it—and that seems to be the implication in all the incitements to try—then clearly it is inefficient, to say the least, to attempt to appeal to students without knowing whom we should appeal to, what we should do, and how we should do it. In a highly competitive market, the seller must have as complete a knowledge as possible of his potential consumers' propensities, preconceptions, and prejudices if he is to tailor his product for maximal appeal—or if he is to present his product in such a way that its merits are evident to the various publics making up his market.

Such terminology is repugnant to many readers, I dare say, but the fact of the matter is that once we equate scientists and national survival, once we talk about recruiting youngsters for careers in science, we have taken science from the ivory tower into the market place, and in a society dedicated to the market place and to consumption we must be prepared to use the techniques and philosophy which the society understands and responds to. Perhaps this cannot be done vis-à-vis science; perhaps it shouldn't be done. I am not prepared to argue either way; I simply wish to point out what the consequences seem to be if one acknowledges that there is a problem of motivating youngsters to go into science rather than into some other career. The moral which seems abundantly evident to me, at least, is that there has been for some time a crying need for a systematic study of the stereotypes, and the underlying values that are held by high-school students about the life and times of the scientist (*5*).

There are techniques for carrying out such studies, and they have proved their value in numerous other situations where a knowledge of the values and beliefs of the potential consumer was a necessary precondition for a marketing or educational program. Until we know these stereotypes and their associated parameters, I fail to see how we can decide *what techniques* directed to *which groups* containing *what content* have the most likely chance of payoff—and even what that payoff might be! To be sure, knowledge derived from a sample of interviews with students is not sufficient by itself for resolving the problem, but on the basis of the proved utility of such information for understanding and solving analogous situations, it would seem that such a study is an absolutely necessary prerequisite.

An Aspect of the Stereotype Problem

Before outlining an appropriate approach to a survey study, I should like to suggest the kind of complexity connected with the motivation problem which makes such a survey indispensable. It should be clear that what is to follow is only an example, only one of many contexts in which the motivation problem might be approached. It may or may not be a useful approach upon which to base questions for such a survey: it is a framework which some readers may find insightful, whereas others may reject it out of hand, preferring some other set of analytic categories. It is a congenial framework for me, and I use it simply to describe one possible problem and to set the ball rolling.

When we consider the direction and content that motivating materials should have, it is appropriate to recognize that there are very likely to be two broad audiences to whom we might want to appeal. I will borrow a terminology and concept from David Reisman and refer to these audiences as the "inner-directed" student and the "other-directed" student (*6*).

Among his other qualities of character, the

inner-directed student has predominantly those that are associated with the classical scientist and from which many of the popular stereotypes about scientists derive: unswerving and selfless devotion to the quest for knowledge.

The other-directed student, swayed by the values of his direct and indirect contemporaries, is the predominant product of our times, for better or for worse. They are the ones who answered Barnes' question with such responses as "Duke Snider is one of the 10 best-dressed men. If he was a scientist, would he be?" These are the students whose stereotypes about scientists are reinforced by such newspaper descriptions of scientists as, ". . . [Whitcomb] is a 34-year-old scientist who has been courting laboratory pallor since he was 12. . . . His sister had to find him a date for his senior prom. He is still a bachelor. . . " (*7*). The other-directed student may well be the one who is tacitly and generally referred to when plans are promulgated for circularizing high-school students on the advantages and glamour of science as a career, on his duty to his nation, and when plans are proposed for raising the status and pay of the scientist in order to make a career in science more attractive.

There are, of course, some inner-directed students; we have not lost them all yet. Perhaps we never shall. But certainly it is becoming more and more difficult in these days of "group adjustment" for a youngster to be idiosyncratic in the eyes of his peers, his parents, and teachers, and still maintain the sense of inner security and inner drive that will permit him to go about his independent way as a "meat ball" in high school and an "egghead" in adult society, devoting himself single-mindedly to science. It might seem that there is no problem in motivating these students to choose science as a career.

I submit that there may, in fact, be a serious dilemma here: the same appeals cannot be used to the inner-directed which will also attract the other-directed student. Money, status, success are likely to have stereotyped implications of other-directedness for the inner-directed which make them repugnant to him or her. I. I. Rabi's comments seem not inappropriate here: "Such is the spirit of the time that it is difficult if not impossible to communicate the feeling of dedication and reverence which all physicists have for our discipline. Others do not seem to understand the emotional commitment we have to expand and deepen our understanding of nature, nor does the quest seem to be particularly important except under the aspect of the conquest of nature. . . . What disturbs and frightens the scientists is the increasing tendency to treat science and the scientist as commodities. . . . The great drive now going on to increase the number of scientists and engineers takes on the appearance of stockpiling of tungsten or copper" (*8*).

There are still academic careers today in the arts and humanities which provide much of the seclusion and independent (that is, nonteam) research facilities and contemplative environment, and these areas of creativity may well appeal more than science to the inner-directed. Again, the appropriate means for attracting these youngsters requires a systematic knowledge of their stereotypes about science as a career.

Thus, it may be that for the other-directed student the stereotype of the scientist is that of the now culturally unstylish inner-directed type of person, while for the inner-directed student the stereotype of the scientist may appear to be the culturally popular other-directed type of person. Whether or not this is wholly or even partially the case cannot, in the nature of the situation, be decided by a vote or by the impressions of those adults concerned with the problem, but only by a careful, systematic, statistically reliable survey of the high-school students who are the object of this concern.

There is an ancillary problem pertaining to the problem of motivating people to choose science as a career, and it certainly deserves more than the passing comment it receives here: it is entirely possible that an other-directed orientation toward life is incompatible with the sort of scientific creativity that seems to be in such short supply. We have no definitive evidence on whether or not the kind of single-mindedness and devotion to science stereotypically ascribed to the geniuses and great men of science, and an environment sympathetic to such preoccupation, is a necessary condition for the production of great science. There are a few tentative studies and observations that suggest that this combination of temperament and environment may be profoundly important, or at least has been so in the past. If it is determined that the inner-directed way of life remains a basic prerequisite, then a determination of the means for maintaining it—if, indeed, it can be maintained—in a primarily other-directed society will require all the detailed and systematic knowledge that we can bring to bear. I submit that without such a survey as the one proposed here we will neither know the extent of our problem nor the possible pathways to its solution.

An Approach to the Study of Stereotypes

A study of the stereotypes of students might profitably follow a program as outlined in the following

sections. But before doing so, let me make clear that this outline is not intended to be a recipe for undertaking a survey. The procedural details are, for the greater part, excluded. What I want to emphasize is not procedure but rather approach and the reasoning behind the approach. I do not want to dwell, so to speak, on aspects of laboratory technique. Rather, I want to outline the philosophy of research design and the prerequisites that must be met if data collecting is to be efficient and meaningful.

Phase 1. Selection of the sample of student respondents. The chief questions to be answered before deciding on the size of the sample and the best manner in which to collect it have to do with the following problem. Of all the possible sources of science recruits among high-school students, what factors associated with these sources are likely to be important when it comes to implementing the findings? This may appear to be a bit question-begging, but it hardly need be pointed out to scientists that an investigation of any matter, if systematically carried out, implies the existence, preferably explicit, of hypotheses about what factors are or are not likely to be relevant to the goal of the research. Similarly here. Presumably we might feel that such items as IQ, rural or urban environment, parental socioeconomic and intellectual background, school size and educational facilities, personality characteristics, all would be background factors that could significantly contribute to the perceptions of students regarding science as a way of life. Moreover, knowledge about the differential relationships of such factors to stereotype and value patterns would be very useful when the time came to design optimum means for appeals to these youngsters from various kinds of backgrounds.

Once it has been decided what factors are believed to be pertinent, the survey can be designed either to preselect samples representing each factor or to use a random sample that will be very likely to include all these groups in amounts proportionate to their distribution in the population of high-school students. (There are many methods for actually selecting the students for the sample. For example, it could be determined that each state is to be represented. Then a random selection from lists of high schools in each state could be obtained by taking every *n*th name from such a list. Within the chosen schools, every *p*th student could be chosen from the registration records. Of course, cooperation from the schools would be necessary. With appropriate auspices sponsoring the study, this should present no insuperable problems.)

One way or the other, attention to these background variables would insure that the questionnaire or interview would obtain the necessary information to pin down the student's relationship with these various categories. The actual size of the samples could only be determined once the cross-tabulations to be run were decided upon (and this should be done as much as possible *before* the data are collected) and once the permissible sampling errors are agreed upon. As is generally the case, the complexity and accuracy of the data obtainable depend on the amount of money available, and compromises in one or the other, or both, are common.

It would also be necessary, depending on the subtlety of the information to be obtained, to decide whether the study was to be based on face-to-face interviews or on written questionnaires, or some combination of both, in which most of the sample filled-out questionnaires and a subsample responded to more exhaustive but carefully related systematic interviews. Again, cost is a major parameter since interviews are much more expensive, other things being equal.

Phase 2. Selection of questions to reveal the stereotypes. Information of the depth and subtlety required cannot be wholly obtained by the usual simple and direct questionnaire procedures. It will be necessary, in addition, to use projective techniques such as the sentence completion test (for example, When it comes to being popular, scientists are ————) and the Thematic Aperception Test (for example, the student is shown a picture of a sleek office and a bedraggled man with a beard standing in the middle of it; the student is asked to make up a story about what is going on). From the content of the stories or the phrases with which sentences are completed, it should be possible to determine the nature and quantitative distribution of various stereotypes and underlying values about science and scientists. Of course, in order that the vast variety of responses given to such material be quantifiable, it is necessary to invent and define categories in which many answers that seem to mean essentially the same thing can be treated as if they in fact meant the same thing. This is clearly an abstracting process, and as such, information is lost. Therefore, as is the case with all conceptualizing activities, these abstractions can be more or less useful for understanding the events so grouped as related. Of course, no absolutely guaranteed picture of reality can be derived from these methods, but they have been good enough to pay off handsomely in market and motivation research in other areas.

The actual questions to be asked and the categories to be invented will depend on what types of information are expected to be illuminating

about the three general questions stated in the next paragraph and what types of information are expected to be useful as a means for constructing methods for better apprising the high-school student of the "realities" of life vis-à-vis careers. Undoubtedly, many studies would be enlightening on this subject, and it is to be hoped that more than one would be undertaken. Each would necessarily stress the interests and experiences of the sponsors, their advisers on adolescent behavior and social structure, and the professional survey organization that would supply the "know-how" for question design and survey implementation. There are three types of responses which any set of questions must elicit in order that such a survey study may realize its goals:

1) In terms of their stereotypes and the values underlying them, what are students striving for when they visualize the kind of world they want to live in and the kind of persons they want to be?

2) What do they *not* aspire to, either because they have a positive aversion to certain values and the stereotypes they associate with them or because they are ill-prepared to consider them because of unfamiliarity or ignorance about their existence?

3) What are the values and aspirations that they ascribe to scientists, as implied in the stereotypes they hold about scientists and science?

Phase 3. Analysis and evaluation of the data. Simple tabulations can and should be made indicating the percentage of adolescents holding particular stereotypes and values about the life they want to lead and about the life they think scientists lead. However, the kind of analysis that will provide the most insightful appreciation of the magnitude of the motivation problem will come from cross-tabulations of the responses of each participant to each of the three response categories outlined in the preceding section against the other categories, supplemented with a further partitioning of these patterns of response in terms of the background variables. This having been done, two types of information emerge:

1) In what areas of values and aspirations are the stereotypes about the scientists' ways of life perceived as compatible with the aspirations of the adolescents, and in what areas are they incompatible?

2) What proportions of students from which combinations of background factors hold which patterns of values and stereotypes toward life and toward science?

A further important step may be taken toward the over-all evaluation of the motivation problem, if it is possible for agreement to be reached by qualified persons, as to whether there are special characteristics about the life of the scientist and, if so, under what particular social circumstances these make him especially similar to or different in values and aspirations from other groups in the society. If this can be done, then it should be possible to determine in what areas adolescents have essentially correct perceptions of the scientists' ways of life and in what areas they are essentially incorrect.

Phase 4. Application of the information obtained. With this sort of systematic and statistically reliable picture of the state of mind of various pertinent groups of youngsters, it should then be possible to tailor appeals along the following lines.

1) When stereotypes about scientists are inadequate or incorrect, information can be supplied to the appropriate types of adolescents which have at least the potentiality of correcting these misconceptions, and the potentiality should be substantially increased, in some cases at least, by presenting the information in a manner compatible with other values and stereotypes they accept about the life they aspire to and the life they live.

2) When the scientists' ways of life are compatible with the values and aspirations of particular groups of students, the students can be made especially aware of this by having informative materials, in which this compatibility is emphasized, directed specifically to them.

Conclusion

Finally, there may be some merit in anticipating two protests that, I suspect, will be sustained by some readers. Protest one: How do we know all this effort will result in a worth-while payoff? In a sense, of course, we don't know. But I suggest that, on the basis of the results of studies of problems not unrelated in complexity and subtlety to this one, it would be safe to predict that the payoff could be no worse than that deriving from *ad hoc* estimates, based on experiences of necessarily restricted representativeness, of what the mind of the adolescent is susceptible to. Whether or not the effort to get a better payoff is worth making is answered, for me, at least, by one's estimate of the seriousness of the recruitment problem. Protest two: The approach, as implied in the program, is undemocratic. Would it be more democratic if motivational materials were derived from the impressions of scientists and interested laymen as to how best to appeal to the guessed state of mind of the students than it would be to base the best appeal on reliable knowledge of the actual state of mind of the students? Are present merchandising methods undemocratic? Are the various tech-

niques the United States Government uses in its overseas educational campaigns undemocratic? All use techniques not unlike those outlined here as a basis for designing their appeals. Finally, there is nothing in the program which attempts to distort or misrepresent the role of the scientists to the students. Indeed, to the extent that democracy requires, for its effective operation, enlightenment, it would seem that efforts to inform effectively and to counter misinformation are in the best American tradition.

References and Notes

1. The views expressed here are my personal ones and should not be construed as those of the organizations with which I am associated.
2. "Students scorn science careers," *Washington Post* (22 Nov. 1955).
3. H. H. Remmers, "Physical science aptitude and attitudes toward occupations," (Division of Educational Reference, Purdue University, Lafayette, Ind.) Remmers has queried his sample on a number of items that give surface indications of some of the stereotypes held by high-school students vis-à-vis some careers, including ones in science. The responses clearly indicate that deeper probing in the areas outlined in this paper should provide information of considerable significance.
4. A classic statement on the nature and function of stereotypes is to be found in W. Lippman, *Public Opinion* (Macmillan, New York, 1922).
5. Because of the primary role of parents and teachers in communicating culture values and stereotypes to the young, it would be desirable to survey them along lines parallel to the study of the adolescents, not only to ascertain the relationship between their perceptions of society and those of the students they are inculcating, but because it is partially through these adults that revisions in the values and knowledge of the students would be attempted.
6. These concepts are subtly and elegantly developed by D. Reisman, N. Glazer, R. Denney, *The Lonely Crowd* (Yale Univ. Press, New Haven, Conn., 1953).
7. "Air scientist got start when 12. Designer of wasp-waist airplane left games to make model planes," *New York Times* (3 Oct. 1955).
8. I. I. Rabi, "To preserve the scientific spirit," *New York Times Magazine* (12 Feb. 1956), p. 14.

Meteorology in the International Geophysical Year

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HERE is a rotating sphere named the "earth" moving through space and separated from it by a thin mantle of air that is proportionately as thin as the skin of an orange. Boring down into the mantle are cosmic rays, meteors, radiations from the stars, and, most important, radiations and energetic particles from the sun. The bottom of the mantle of air, which is deformed by mountains and plateaus, absorbs heat and water vapor, and its movement is opposed by friction as the air moves over land and water. The atmosphere repays its debt to the sun and space by passing energy upward in the form of infrared radiation.

The mantle of air is capable of a bewildering mixture of orderly and haphazard motions. These decrease in size and regularity from the thousands-of-miles-long trade-wind belts, to the large-scale horizontal waves in the westerlies, to the hurricane, to the tornado, to the dust-devils, and finally to the tiny unseen whirls and vortices that couple the motion of the atmosphere to that of the earth.

There are many things that meteorologists do not know about the winds, but one thing they are certain of is that all atmospheric motions are derived from the fact that the tropical and subtropical regions of the earth (between the Equator and 38° of latitude) absorb more solar radiation than they radiate away, while the rest of the world radiates more than it receives. As a consequence, the air that is warmed in the tropics moves toward the poles and initiates a global circulation system that determines the nature and extent of man's activities in surviving on this planet.

From time immemorial man has recognized his critical dependence on the state of temperature, precipitation, and wind, known as weather, and has tried to accommodate himself to its vagaries. He has tried to predict the weather, first from what he could observe locally and then, as the inadequacy of this extent of observation dawned on him, from farther and farther beyond his horizon and from higher and higher into the atmosphere. Various inventions such as the telegraph, radio, kite, balloon, airplane, and rocket have given sudden and important increments to his means of observing and reporting in his attempts to catch an instantaneous glimpse of a larger and larger volume of the atmosphere. Even today, however, only about one-fifth of the total atmospheric mass is adequately probed each day. This is not surprising, for the ocean of air in which we live is so vast that, if it were divided up for observation among all the human beings on earth, each person would be responsible for watching approximately 2 million tons of air.

Despite the obvious absurdity of trying to predict the future state of the atmosphere when its present state in all important respects is not known, the daily weather forecasts for areas where observations are most numerous, although they are far from perfect, are significantly useful. This is because, for short periods of time—a day or two—only those atmospheric events that occur within a few thousand miles can influence the local weather. For forecasts of a week or two we must have weather observations from most of the Northern Hemisphere and for longer range forecasts, from most of the world. However, lack of sufficient observations from distant oceans, deserts, jungles, mountains, and polar ice caps is not the only reason for our inability to predict with useful accuracy the weather from weeks to months in advance. Our understanding of the mechanics of the atmosphere is still woefully inadequate. But if past developments in meteorological science serve as a guide, improved understanding follows closely on the heels of an expanded observational network. Several generations of meteorologists have exploited this relationship by supporting wholeheartedly the First and Second Polar Years in 1882–83 and 1932–33 and now the International Geophysical Year of 1957–58.

Atmospheric Circulation and Transports

What specific benefits do meteorologists expect to gain from this third international undertaking? First, it will extend the existing meteorological observing networks (already much more extensive than those established at the height of the Second Polar Year) laterally and vertically into the unknown. The expanded measurements will permit more accurate estimates to be made of the global wind systems and the poleward transports of atmospheric energy, momentum, and water vapor. For the Northern Hemisphere, the mean annual poleward flux of all forms of energy, the latent heat of the vaporization component alone (in the form of water vapor), and the angular momentum of the winds have been computed by Starr and White (*1*) from scattered, incomplete observations of wind, temperature, humidity, and barometric pressure for the year 1950. The results are shown in Fig. 1. Note that all three transport curves show a maximum at middle latitudes, which are also the boundary between the tropical regions where excess solar radiation is received and the polar regions where deficient solar radiation is received.

It would appear that the transporting of energy and momentum poleward might be accomplished in an infinite variety of ways—that is, by means of whirls and eddies of all sizes and orientations. However, the atmosphere is subject to a number of restraints, the most important of which is the frictional coupling that enables the atmosphere to rotate with the earth. The earth's rotation, the distribution of land and ocean, the topography, and the internal frictional stresses of the atmosphere exert restraints that limit the number of possible flow patterns in the atmosphere.

It appears that the horizontal eddies comparable to the familiar "highs" and "lows" shown on weather maps are chiefly responsible for the major poleward transport of energy, moisture, and momentum, at least in middle latitudes. At lower latitudes, the large vertical eddies—known as the Hadley cells—extending in latitude from the equator to 30° and in height from sea level to 10 miles, are probably responsible for the major transports.

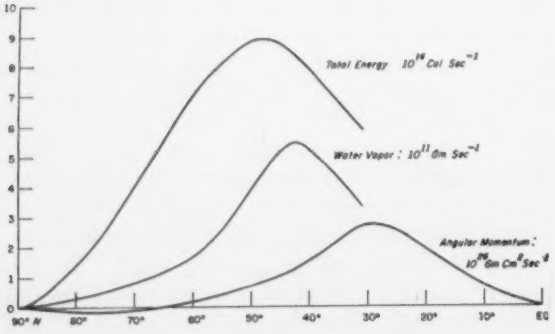

Fig. 1. Poleward flux of atmospheric energy, water vapor, and angular momentum for the year 1950 (after Starr and White, *1*). The ordinate unit is shown next to each curve. The abscissa shows the latitude across whose total length the flux is computed.

Of course the transport of energy, momentum, and water vapor at any one time may differ markedly from the average curves shown in Fig. 1. The differences are caused by a variety of factors, such as changes in cloudiness, wind, and temperature, that govern the exchange of energy and of momentum between the earth and the atmosphere. These factors themselves are determined by the particular scale and type of air motions that do the transporting. The cyclic interplay between cargo and vehicle is far from understood. The study of motions and transports in the nearly maritime Southern Hemisphere, which will be made possible in a skeleton form for the first time during the International Geophysical Year, and comparison with similar quantities in the land-locked Northern Hemisphere should greatly facilitate our understanding of this complicated world-wide "feedback" mechanism.

Meteorology in Relation to Other Geophysical Sciences

A second compelling reason for meteorological interest in the International Geophysical Year is the role of meteorology as the largest common denominator of all the geophysical sciences—from those dealing with the oceans to those concerned with the outer fringes of the atmosphere.

Oceanography. The interplay between the atmosphere and the ocean is so intimate that it is useful at times to consider the atmosphere and ocean as one medium separated by an internal surface across which there is a discontinuity in density and velocity. The exchange of heat, moisture, momentum, gases (such as carbon dioxide and oxygen), elements (such as sodium, chlorine, potassium, calcium, and magnesium) across this interface has profound influence on the subsequent behavior of the atmosphere and ocean. In supplying the atmosphere, the oceans serve as a warehouse of nearly infinite capacity for heat, moisture, and carbon dioxide. In turn, the faster-moving atmosphere supplies the oceans, particularly the surface layers, with much of their momentum.

The contributions made by the ocean currents to poleward transport of some of the excess energy accumulated by solar radiation in the tropical latitudes is still not accurately determined, but it

appears to be at least 10 percent of that required for global energy balance. The formation of new volumes of cold bottom water in the oceans seems to occur during unusually cold decades (such as that of 1810–20) but it is still a matter for debate among oceanographers whether, in absence of such climatic catastrophes, it would take 15 or 150 or 1500 years for this cold bottom water to overturn and appear on top to depress surface temperatures sufficiently to cause a detectable climatic change. Various salts and elements released by the ocean to the atmosphere serve as important condensation nuclei, which are necessary for cloud formation and ensuing precipitation. The fact that the severe, long-lived wind storm known as the "hurricane" forms mainly over the oceans points to an optimum combination of meteorological and oceanic conditions necessary for its genesis.

Physics of the upper atmosphere. Turning to the other extreme portion of the atmosphere—that which merges imperceptibly into space—we find that here the atmosphere is bombarded by all sorts of energetic waves and particles. The absorption of only a very small fraction of the incoming energy is sufficient to place the thin outer atmosphere in a state of violent agitation that influences profoundly the ionosphere, aurora and airglow, and geomagnetism, but whether such absorption can influence significantly the great mass of the atmosphere below is a moot question. Most meteorologists believe that the considerably larger fraction of solar radiation that passes through the atmosphere and is absorbed by the lowest 10 to 15 miles of air and the earth's surface furnishes the energy for air motions whose influence may extend upward and help determine the nature of the response of the top atmospheric layers to energetic stimulation by solar and other types of radiation.

Cosmic rays. The location of the geomagnetic poles in the polar regions permits the less energetic cosmic-ray primaries to penetrate deep into the atmosphere. But the presence of the areas of unusually low barometric pressure found at sea level in the surrounding regions, particularly near the Antarctic continent, the Aleutian Islands, and Iceland, means that in these areas there is 3 to 5 percent less atmospheric mass to oppose the motion of high-speed particles. This fact, combined with the low temperature of the polar air column, so contracts the atmosphere vertically that various secondary radiations originating from collision of cosmic-ray primaries with air molecules can reach the earth's surface in greater intensity. The height of the 100-millibar surface (below which nine-tenths of the atmospheric mass is found) at Maudheim, in Queen Maud Land, Antarctica, is 5000 feet less than it is at Washington, D.C., while at Thule, Greenland, it is 3000 feet less.

These examples, taken from the top and bottom of the atmospheric mantle, serve to illustrate the complicated interplay of meteorology and its sister geophysical sciences and how intensified observations leading to improved understanding of one branch of geophysics are bound to cast light on the others.

Antarctic Geophysics

The International Geophysical Year will differ markedly from its predecessors, the First and Second Polar Years, in the attention that will be devoted to antarctic geophysics in general and antarctic meteorology in particular. The Antarctic continent, which is twice as large as the United States, has never had more than four or five complete meteorological stations in operation at the same time. During the International Geophysical Year, this number will be increased to nearly 20, not counting an almost equal number of more limited stations on the Palmer Peninsula. The establishment of weather stations in a meteorologically unknown area is always an exciting event, but their establishment in an area as large as Antarctica, with its extremes of radiation, temperature, pressure, and wind, will represent a historic achievement in the exploration of the atmosphere of the planet earth.

The Antarctic affords an opportunity to investigate a wide range of meteorological problems under conditions that are not found elsewhere on earth. These problems include the examination of the thermal, mass, and mobile structure of an atmosphere that is cut off both from direct solar energy for many months and, in contrast to its Arctic Ocean counterpart, from conduction of appreciable heat from below. The sharp distinction between the troposphere (the lower 6 to 12 miles of atmosphere that shows a vertical temperature decrease) and the stratosphere (the upper layer of vertical temperature constancy or rise), so marked elsewhere, is believed to vanish during the polar night over most of Antarctica.

Another problem is whether the flow pattern of the troposphere over Antarctica is dominated by the mid-latitude planetary wave system moving like spokes of a wheel around the Pole—as appears to be the case in the Arctic—or by waves moving radially outward from the interior of the continent —as suggested by earlier meteorological observations—or by both wave-systems. A smaller-scale, but highly important phenomenon, especially for field and aircraft parties, is the drainage of chilled air from the high, icy plateau of the interior down-

ward across the coasts, with average monthly wind speeds of more than 60 miles per hour being reported during the colder half year at some stations on the Adélie Coast.

The existence of a near-uniform thermal and flat snow surface, such as is found for hundreds of miles over the Ross Ice Shelf, will provide an unexcelled natural laboratory for study of atmospheric turbulence and energy exchange between the atmosphere and the snow surface. The incoming and outgoing radiation fluxes, the albedo or reflectivity of the snow surface, the polar whiteout, and the variations of ozone, carbon dioxide, radioactivity, and the chemical content of precipitation will be measured in Antarctica during the forthcoming International Geophysical Year.

Climatic Change and the Earth Satellite

One of the most important goals of the International Geophysical Year is the continuation of older and the initiation of new *epochal* types of measurements by which long-period trends of world climate and atmospheric composition can be determined and ultimately explained. It is not generally realized that much of the climatic warming, which has attracted considerable attention in recent years, is confined to rather restricted areas of the earth, particularly to the North Atlantic subarctic region and the eastern and central United States. Other regions, such as the northwestern United States and parts of central Canada, have cooled appreciably during the past 40 or 50 years. But whether the earth as a whole is warming or cooling cannot be determined from the present inadequate observation networks or even from those planned during the International Geophysical Year. The expanded observations of glaciers to be made during the International Geophysical Year and comparisons with past and future observations will shed much light on which glaciers are expanding and which are contracting, but this will still not be an adequate indication of the trend of global climate as a whole.

The artificial earth satellite which will be launched during the International Geophysical Year will ultimately provide an observation platform from which the global heat balance can be determined. Measurements of the incoming solar radiation and the fraction that is reflected by the atmosphere, clouds, and earth's surface (the earth's albedo), as well as the outgoing infrared radiation from the earth and the atmosphere to space, if carried out over long periods of time (a year or longer), should enable us to learn whether the earth is receiving more energy that it returns to space or vice versa. The long-term excess or deficit of global energy income would be partitioned among atmosphere, oceans, land, and glaciers in some unknown manner.

The difficulties of detecting changes in energy budget of some of these components are illustrated by the following figures. On the average, each square centimeter of the earth's surface annually receives from the sun 175,000 gram calories. If there were complete radiative balance (as most textbooks in meteorology assume) there should be an equal return of energy to space. But, if averaged over a year, there were a 1 percent excess of energy received by the earth, what would this mean in terms of heating the oceans, melting the glaciers, and warming the atmosphere? If all the extra energy were concentrated in heating the oceans and nothing else, this would raise its average temperature by 0.006°C, which could not be detected by present observing stations. Even if the heating were confined only to the surface-mixed layer of the ocean (about 200 meters thick) then the average temperature rise would be 0.12°C, still too small to be measured even with a greatly expanded oceanic observation network.

Suppose that the excess energy were confined to the glaciers, average thickness 2000 meters, and covering 3 percent of the earth's surface; then at the end of 1 year only 9 meters or 0.5 percent of the ice would be melted—an amount too small to be observed except in few places where accurate measurements were maintained.

Again imagine that the excess energy resulting from the imbalance of in- and out-going energy streams were concentrated in the atmosphere. This would raise the average temperature of the atmosphere by 7°C—or by an amount which is believed by geologists to be the difference in world temperature between that of the last ice age and the present time—a difference that would be readily detectable even by our present observation networks.

The determination of the over-all global energy budget plus that of such individual components as the atmosphere and glaciers (with the aid of greatly expanded observation networks) would permit determination of the energy budget changes of oceans and land masses. Thus the International Geophysical Year will unveil a new tool by which meteorologists may soon learn more about the energy exchanges of the planet earth with sun and space, and how the exchanges, in turn, may be translated into climatic (atmospheric, oceanic, and glaciologic) trends on which man's existence depends so crucially.

Changes in Atmospheric Composition

Another type of epochal measurement, while not so glamorous, is quite important. This is the determination of the changing gas and particulate composition of the atmosphere. The International Geophysical Year is occurring at a particularly interesting time in man's occupation of this planet. The rapid burning of fossil fuels in the remainder of this century will release such large quantities of carbon dioxide to the atmosphere that, if burning is continued at present rates and if the carbon dioxide is not absorbed by the oceans, the amount of carbon dioxide in the atmosphere, which now occupies 0.03 percent of the volume, will nearly double. Since the fossil fuels will soon be mostly consumed and replaced by nuclear energy, this experiment will not be repeated again on such a mammoth scale. Global measurements of the carbon dioxide content in the atmosphere and oceans will help answer the following questions: How rapidly does the ocean absorb the increased carbon dioxide that is released to the atmosphere? If there is appreciable lag in the ocean's ability to absorb the extra carbon dioxide (as is now believed), what will be the influence on the atmospheric heat balance of a large increase of carbon dioxide when it is considered that carbon dioxide is a particularly effective absorber of radiation near 15 microns—not far from the peak of the spectrum of the outgoing thermal radiation from the earth to space?

We can ask additional basic and grave questions resulting from man's use of the atmosphere as a dumping ground. Will particulate matter released into the atmosphere interfere with the natural cloud- and precipitation-producing processes? Will such particles cause an increased albedo and so deprive us of an important part of solar radiation we now get? It is known from the cruises of the *Carnegie*, 1914 to 1928, that artificial contaminants decreased significantly the electric conductivity of the atmosphere over the open ocean. Could this have an important effect on the cloud-drop coalescent process that is so important for certain types of precipitation and also on the frequency and severity of electric phenomena such as lightning?

The answers to many of these problems will have to wait for digestion of data obtained during the 1957–58 International Geophysical Year and probably also for the obtaining of additional data from future International Geophysical Years. The world's geophysicists, in planning the observing program of the forthcoming International Geophysical Year, bear a heavy responsibility to future generations in insuring that basic environmental measurements, crucial to life as we know it, are carefully recorded and that new ones are initiated. For this reason, as well as for its contribution to studies of the general circulation of the atmosphere, the Special Committee for the International Geophysical Year (CSAGI) has recently decided that "the nuclear radiation of air and precipitation at the earth's surface and of solid particles deposited on the ground should be measured on a world-wide basis during the IGY."

Reference

1. V. P. Starr and R. M. White, "Balance requirements of the general circulation," in *Studies of the Atmospheric General Circulation*, Massachusetts Institute of Technology, Final Report, Part 1, General Circulation Project (1954), pp. 186–242.

ASSOCIATION AFFAIRS

Preliminary Report of AAAS Interim Committee on the Social Aspects of Science

The council of the American Association for the Advancement of Science, at its 1955 meeting, resolved to establish an "Interim Committee on the Social Aspects of Science." During the past year this committee has made a preliminary study of the present state of science in the United States and its relation to social forces and issues. The committee found that even a cursory examination of this question leads to a serious conclusion: that there is an impending crisis in the relationships between science and American society. This crisis is being generated by a basic disparity. At a time when decisive economic, political, and social processes have become profoundly dependent on science, the discipline has failed to attain its appropriate place in the management of public affairs.

The committee believes that this question demands the most urgent attention of the AAAS and of scientists generally. The present interim report is not intended as a complete consideration of the many interrelated problems encompassed by the area which the committee has studied. Rather, the report represents a sampling of some of the issues which the committee has found to serve as useful points of departure in developing an analysis of the situation. Because of the importance of this matter, the committee believes that any decision on the manner in which the AAAS can best deal with it should be based on extended and broadly conducted discussion among natural and social scientists and other interested persons. The report which follows is intended as one means of initiating this discussion.

Such an undertaking comes at an opportune time. We are at the start of a period in which science holds the promise of making unprecedented improvements in the condition of human life. Any action taken now to assist the orderly growth and beneficial use of science will be of lasting significance.

New Scientific Revolution

A cursory examination shows that society has become far more dependent on science than ever before for the following reasons.

Accelerated growth of scientific activity. The volume of scientific research and development conducted in this country has been increasing at an astonishing rate. In 1930, expenditures for science were estimated at $166 million; in 1953, the amount was more than $5 billion. Allowing for the change in the value of the dollar, this represents approximately a 15-fold increase in research expenditures over the 23-year period. The number of active scientists in the United States in 1930 was 46,000; the present number is probably about 250,000. All estimates of future needs for scientific research and personnel indicate that this growth will continue at an accelerated pace. This rate of growth sets scientific activity apart as the second most rapidly expanding sector of our social structure, military activities being first.

Increased use of scientific knowledge. It is characteristic of the present era that the previously formidable gap between scientific knowledge and its application to practical problems has become considerably reduced. It is now commonplace that calculations based on physical theory move quickly from the scientist's laboratory across the engineer's drafting board and on to actual industrial production. Since 1940 we have experienced a series of classic examples of almost immediate conversion of a scientific advance to a process of large practical impact upon society: antibiotics, synthetic polymers, nuclear energy, transistor electronics, microwave techniques, electronic computers. The greatly narrowed gap between laboratory and factory results from a distinctively new role of research in industry. Scientific investigations were previously regarded by industry as a kind of exotic garden to be cultivated in the hope of producing an occasional rare fruit. In contrast, research has now become a deliberate instrument of industrial development; scientific investigations are consciously undertaken as a means of achieving desired economic gains or, as in several notable industrial laboratories, for the purpose of contributing to our fund of basic scientific knowledge.

Recent advances in science have also created completely new industries. Four major industries —chemical, electronic, nuclear energy and pharmaceutical—represent direct extensions of laboratory experience to an industrial scale. This type of direct transformation of scientific experience to industrial operation is probably unique in human history. Earlier industrial developments were based more on empirical experience than on laboratory science.

Social Position of Science

Science is but one sector of our culture. It is one of the institutions of society, and to a considerable degree society itself governs the development of

science. In the present situation, social forces influence the development of science in the following key ways.

Social demand for technologic advances. From the evidence already cited it is clear that there is a strong social demand for at least some kinds of scientific progress. The fact that industry has made unprecedented investments in research is practical evidence that this type of scientific work is seen as a desirable activity by industrial managers. Government scientific activity, which perhaps reflects a wider range of social forces, has also been very intense in the past 20 years. Accelerated support for scientific research is evident from the increased scale of military research, the growing activities of the National Science Foundation, the greatly increased support for medical research by the National Institutes of Health, and the increasing share of philanthropic funds from private agencies now devoted to research on health and social problems. The following generalizations may be made concerning the distribution of the enhanced research support now enjoyed by American science.

1) The major part of research support goes into applied research and development rather than into basic science. In industrial research, the ratio is about 97/3; in universities about 50/50; in federal agencies (including support for research done elsewhere) about 90/10.

2) Support is heavily slanted toward physical sciences. In 1954, federal research support was divided as follows: physical sciences, 87 percent; biological sciences, 11 percent; social sciences, 2 percent. Industrial research is at least as heavily weighted in this direction.

3) At present a very large part of our total research activities are for military purposes. Of the estimated federal expenditures for research in 1957 ($2.5 billion), about 84 percent is earmarked for matters related to national security.

4) Colleges and universities, which are the site of much of our basic research activities, have become dependent on federal funds for the greater portion of their research support (60 to 70 percent in 1954).

Some of the effects of these factors upon the character of scientific research are discussed in the section on "Internal situation in science."

Public interest in science. There are indications that the public interest in science is not commensurate with the important role of science in society.

1) Shortage of scientific personnel: We face a major crisis with respect to present and future shortages of scientific personnel. In effect, this means that the social environment in the United States does not elicit a maximum interest in science on the part of those individuals who have the capability of doing scientific work, or that our social organization does not permit them to receive the necessary training. This problem is closely connected with the more general question of the present state of public education in the United States. The content of public education has been subjected to a good deal of criticism recently, especially with regard to science and mathematics. Many scientists feel that an official state requirement for graduation from high school which calls for 1 year of "general" mathematics and for 1 year of "general" science cannot be regarded as proper recognition of the importance of science.

2) Attitudes toward scientific work: To some degree the foregoing difficulties reflect a broader problem—that is, a traditional disregard for abstract thinking. More than a century ago De Tocqueville observed, "Hardly anyone in the United States devotes himself to the theoretical and abstract portion of human knowledge." He said that the immediately practical aspects of life were, however, fully appreciated. The same generalization appears to be true today. So-called "practical" men of public affairs and business frequently disregard the advice of scientists and prefer instead to rely on "common sense," but the latter is often construed to mean what Einstein has called "a deposit of prejudices laid down in the mind prior to the age of 18." This problem, particularly as it relates to a lack of interest in scientific careers, has attracted considerable attention of late. Recent surveys indicate that the general attitude exemplified by popular epithets such as "eggheads" and "longhairs" is well rooted in the opinions of young people.

3) Science in the public press and other media: By all standards, science receives an unduly small share of the budget of newspaper space or broadcasting time. The number of books and magazines devoted to disseminating public information about science is correspondingly small. The immediate reasons for this state of affairs are manifold. It is clear, however, that the situation reflects a rather low level of interest in science on the part of the public, or more probably of those who attempt to judge the public mind for purposes of directing the media of information.

Internal Situation of Science

How has its recently accelerated rate of growth and the general nature of the social influences upon it affected the character of American science? Some brief and approximate answers may be made.

Unbalanced growth. The growth of our scientific organization has not been an orderly process. Growth has been based less on internal needs of science than on the interest of external agencies in possible practical results. In a sense, the speed and direction of the development of science has been determined by the users of science rather than the practitioners of science. Agencies which use scientific knowledge (for example, industrial management, military establishments, medical agencies) have undertaken to encourage, and pay for, scientific research of a sort which seems to promise information that might be useful to their own specific purposes. The disproportionate growth of the physical sciences as compared with biological and social sciences to some degree reflects the interests and superior financial resources of the industrial and military agencies that support science.

The effects of this unbalanced development are already being felt. Generally speaking, we sometimes find ouselves embarking upon new ventures, based on advances in chemistry and physics, before we are adequately informed about their consequences on life or on social processes. Some of the resultant difficulties which we have already made for ourselves are described in the section on "Major social issues of scientific origin: signs of trouble."

It should be recalled that this unbalanced growth takes place within the framework of a shortage of personnel. This situation has very naturally given rise to a somewhat disorganized competition for students, which further accentuates the disparate pattern of development of the various sciences.

Inadequate progress in basic research. It is well known that the creative source of all technologic advance is the free inquiry into natural phenomena that we call basic, or "pure," science. However, as has already been indicated, the great bulk of our present research activities represent the development of practical applications of the knowledge generated by previous advances in pure science. It has been pointed out repeatedly that many of our current technologic advances are based on the application of accumulated basic knowledge which is perhaps 20 to 30 years old. The progress of basic science does not appear to be keeping pace with the development of applied science. Some observers even feel that there has been an absolute decline in the amount of highly creative research of the type that leads to major advances in our knowledge of nature. They point out that our present understanding of the structure of atoms and molecules and of the behavior of living cells goes back to great illuminating propositions that are 25 years or more old.

Difficulties in scientific communication. New information is the major goal of scientific research, and communication of information is vital for all scientific progress. However, the rapid, rather disordered growth of science has placed a severe strain on the channels of scientific communication.

1) Communication among the divisions of science: The problem of adequate dissemination of the results of current research has become a matter of great concern. The growth of our research establishment and the resulting increase in the numbers of scientific communications have made the problem of "keeping up with the literature" quite serious. It is now widely recognized by scientists that the existing system of publication and distribution does not fill their needs. Published articles and monographs have not kept up with the current knowledge in many fields. The number of journals is insufficient (publication delays of 1 year are common) and methods of abstracting, indexing, and reviewing are inadequate. It is becoming rapidly more difficult for scientists to find out what their colleagues know. The situation is particularly bad with respect to articles printed in foreign languages (Russian, especially) which investigators are too frequently incapable of reading. Some observers have already urged the establishment of scientific information centers from which subscribers could receive transmitted reproductions or teletyped abstracts obtained by electronic scanning devices. Such centers would require government investment of about $150 million. That proposals of this magnitude are under current discussion is an indication of the severity of this problem.

Proper communication among scientists is not, however, merely a matter of developing proper recording, cataloging, and searching devices. Face-to-face meetings, which bridge the barriers of specialization, are an obvious necessity for the ordered growth of human knowledge. There is a widespread feeling among scientists that scientific meetings which bring together investigators from different fields of science are a necessity. But, with some distinguished exceptions, such meetings have been difficult to establish thus far.

2) Imposed restrictions of free communication: Although government support has been a major source of recent scientific growth, it has been accompanied by influences which are in some respects inimical to the basic needs of science. Complete freedom of communication, regardless of national boundaries, is an essential aspect of science; nevertheless, along with government support American science has been burdened with practices that restrict the free flow of information. The interchange of scientific information is some-

times restricted unduly by the overclassification of data that affect national security. It must be acknowledged that at certain times, and with certain types of data, restriction of exchange of information is necessary so long as scientific progress continues to have military activity as one of its chief values. The immediate problem is to limit such restrictions to a minimal area. The ultimate problem is to free society as a whole and thereby science itself from the tyranny of war.

Not all artificially imposed restrictions on communication result from government requirements. There is an understandable tendency on the part of industry to protect its investment in research by restricting distribution of its results. As a greater share of research is taken on by industry, especially in those areas where expensive, complex operations are involved, this problem will become of greater significance. It is ironical to note that a recent Conference on the Practical Utilization of Recorded Knowledge—Present and Future (at Western Reserve University, January 1956), which devoted a good deal of attention to the problem of improved dissemination of knowledge, found it necessary to hold part of its deliberations behind closed doors and to refrain from publicizing the full record of these "confidential" sessions [*Am. Scientist* (April 1956)].

Unrestricted communication is but one facet of the free intellectual environment that is as important to scientific creativity as it is to all other fields of human endeavor. If society is to benefit broadly and effectively from the efforts of modern science, and if science in turn is to be enriched by contributions from other fields, the social order must provide the greatest possible intellectual, social, and personal freedom for scientist and nonscientist alike, at every level of the social structure.

Major Social Issues of Scientific Origin: Signs of Trouble

How well have we solved those social issues which are most closely related to scientific or technologic knowledge? Most of our successes are self-evident. Scientific knowledge is being applied to the development of a new industrial system capable of greatly increasing, in both quantity and quality, the total wealth of man. We are creating a remarkable establishment for medical and related research, which has given us mastery over many human ills and has prolonged the span of life. Nevertheless, scientific problems which influence social processes have become an arena of serious difficulties. In some situations our enhanced ability to control nature has gone awry and threatens serious trouble. Some examples follow.

Radiation dangers. It is hardly necessary to point out at this time that the difficulties created by the dispersion of radioactive materials from nuclear weapons have caused considerable concern in this country and throughout the world. Regardless of one's attitude toward the necessity of setting off nuclear explosions for testing purposes, there is considerable evidence that this aspect of human control over nature is a potential danger to life. The recent controversy over the immediate significance of this problem shows that we have not yet developed methods for the orderly determination of the facts, in an area in which such facts may influence the health of the whole population of the earth.

Food additives. The enormous growth of industry based on organic synthesis, coupled with the already mentioned tendency toward rapid exploitation of scientific knowledge, has resulted in a great increase in the number of man-made compounds now used in foods or otherwise ingested or absorbed by human beings. The period of use of many of these substances has been rather short, and possible undesirable long-range biological effects have not yet had time to appear. Laboratory methods for studying delayed biological effects such as carcinogenicity are unfortunately difficult to manage and equivocal in interpretation. Consequently, the establishment of certification procedures which might assure the public that a given additive is harmless is a difficult matter which has been the subject of considerable discussion and controversy. Nevertheless, additives are in use, and the problem of making a reasonable determination of their safety must be faced.

A parallel situation exists in connection with the health hazards that arise from the dissemination of fumes, smogs, and dusts by industrial plants and from automotive and other combustion processes. The harmful biological effects of these agents usually appear a long time after the commercial usefulness of the process is established and large-scale operations are in effect. By then remedial procedures are very difficult to carry out.

In these cases the use of substances resulting from scientific advance has already outstripped the base provided by our scientific knowledge. Information on the biological effects of a new substance is acquired at a very much slower pace than the rate at which new substances are made or put into use. It is probably inevitable that biological research will move more slowly than either chemistry or physics, but it should be expected, therefore, that we would put correspondingly more effort into research on biological phenomena. The opposite is the case. Less than about 10 percent of our total

research expenditure goes into biology and medicine.

Natural resources. The natural resources contained in the crust of the earth comprise the major source of our wealth, and it is a matter of concern that they be properly used. The natural laws which regulate the character and behavior of these resources lie within the domain of the various sciences. However, social decisions actually control what is done with our resources. It has been pointed out by Paul B. Sears that these decisions are rarely in the hands of scientists. Under these circumstances large-scale changes in our natural resources have occurred without proper consideration for the consequences which might be expected from a knowledge of natural laws.

An illuminating example cited by Sears is the recent flood disaster in New England. He points out that the widespread damage caused by these floods was a direct consequence of the unplanned crowding of housing areas into the river floodplains. This was a failure to recognize and act upon physical events easily foreseeable from a relatively simple knowledge of the landscape. The declining water-table caused by irrigation practices illustrates a similar disregard for natural laws. In these and more complex instances, the harmful outcomes of the given practice can be predicted by appropriate technical analysis.

These examples show that social factors condition the use to which scientific knowledge is put. Perhaps the most striking example of this phenomenon is modern warfare, which represents a social decision to use the power of scientific knowledge for purposes of destruction and death.

Some Conclusions

The present state of science and its relation to the social structure of which it is a part are characterized by the following general features.

1) We are witnessing an unprecedented growth in the scale and intensity of scientific work. Research has placed in human hands the power to influence the life of every person in every part of the earth.

2) This growth has been stimulated by an intense demand for the practical products of research, especially for military and industrial use. Agencies which use the products of research are willing to provide financial support and other forms of encouragement for science, but they show a natural tendency to favor those fields and aspects of science which most nearly relate to their needs.

3) The public interest in, and understanding of, science is not commensurate with the importance that science has attained in our social structure. It cannot be said that society provides good conditions for the proper growth of science. The effort to explain the nature of science to the public is slight compared with the public attention now given to other less consequential areas of human activity. Interest in science as a career is so restricted that a serious and worsening personnel situation has arisen.

4) For reasons such as those just cited, science is experiencing a period of rapid but rather unbalanced growth. Basic research, which is the ultimate source of the practical results so much in demand, is poorly supported and, in the view of some observers, lacks vigor and quality. Areas more remotely connected with industrial and military applications, such as biology and the social sciences, are also not being adequately supported. The present period of rapid, unplanned growth in research activities is precipitating critical difficulties in connection with the dissemination and analysis of scientific information.

5) The growth of science and the great enhancement of the degree of control which we now exert over nature have given rise to new social practices, of great scope and influence, which make use of new scientific knowledge. While this advance of science has greatly improved the condition of human life, it has also generated new hazards of unprecedented magnitude. These include the dangers to life from widely disseminated radiation, the burden of man-made chemicals, fumes, and smogs of unknown biological effect which we now absorb, large-scale deterioration of our natural resources, and the potential of totally destructive war. The determination that scientific knowledge is to be used for human good or for purposes of destruction is in the control of social agencies. For such decisions, these agencies and ultimately the people themselves must be aware of the facts and the probable consequences of action. Here scientists can play a decisive role: they can bring the facts and their estimates of the results of proposed actions before the people.

Need for Action: the Role of the Organizations of Science

This appears to be a critical time for review of the general state of science and its relation to society. We are now in the midst of a new and unprecedented scientific revolution which promises to bring about profound changes in the condition of human life. The forces and processes now coming under human control are beginning to match in size and intensity those of nature itself, and our total environment is now subject to human influence. In this situation it becomes imperative to

determine that these new powers shall be used for the maximum human good, for, if the benefits to be derived from them are great, the possibility of harm is correspondingly serious.

As scientists we are particularly concerned with determining how we should meet this situation, both as individuals and through our organizations. In marked contrast to other associations, scientific societies seldom consider the social and economic position of their group. Action taken on social problems with a scientific or technologic base are sporadic and usually forced. Yet the democratic system is operated to a considerable extent under stimulus from groups, each representing the views and interests of its members.

Business and labor are not backward in presenting their opinions on social questions that affect them. They make sure that in the final decision their views have been considered. There are many who think that the viewpoint of scientists should also be stated publicly. In fact, if others express their opinions and scientists do not, a distorted picture will be presented, a picture in which the importance of science will be lacking and the democratic process will become to that extent unrepresentative.

The need for action is serious and immediate. Consider, for example, the situation related to the biological hazards of radiation. It is now 9 months since the radiation committees of the National Academy of Sciences issued a report that called for a series of immediate actions including, among others: (i) the institution of a national system of radiation exposure record-keeping for all individuals; (ii) vigorous action to reduce medical exposure to x-rays; (iii) establishment of a national agency to regulate the disposal of radioactive wastes; (iv) establishment of an international program of control and study of radioactive pollution of the oceans; (v) considerable relaxation of secrecy about dissemination of radioactivity. In addition, the committees pointed out that "The development of atomic energy is a matter for careful integrated planning. A large part of the material that is needed to make intelligent plans is not yet at hand. There is not much time left to acquire it."

There is no evidence that these urgent pleas for action have yet met with any significant response. Clearly, this is a matter that requires the persistent attention of all scientists. It exemplifies the pressing need that scientists concern themselves with social action. In this situation, the AAAS carries a special responsibility. As one of our past presidents, Warren Weaver, has said: "If the AAAS is to be a vigorous force for the betterment of science, it cannot continue in the face of crucial situations with closed eyes and a dumb mouth." This responsibility has already been recognized. What is needed now is a way to meet it.

WARD PIGMAN, *Chairman*
University of Alabama Medical Center, Birmingham

BARRY COMMONER
Washington University, St. Louis, Missouri

GABRIEL LASKER
Wayne State University, Detroit, Michigan

CHAUNCEY D. LEAKE
Ohio State University, Columbus

BENJAMIN H. WILLIAMS
Industrial College of the Armed Forces

AAAS Council Meeting, 1956

The 1956 meeting of the Council of the American Association for the Advancement of Science was held in New York City during the Association's annual meeting. The two sessions were convened at 4 P.M. on 27 Dec. and 9 A.M. on 30 Dec. Paul B. Sears, president of the Association, presided over both sessions. The meeting was the largest in the Association's history, with 156 present at the first session, and 108 at the second.

Elections and Officers

By mail ballot prior to the meeting, the Council elected Wallace R. Brode as president-elect, and elected Alan T. Waterman and reelected Paul E. Klopsteg to 4-year terms on the Board of Directors. The board announced that it had elected William W. Rubey to serve the unexpired year of Brode's term as a member of the Board of Directors. Also elected by the Council were the vice presidents and chairmen of sections whose names appear in the April issue as part of the complete list of Association officers. By vote of the Council, the Board of Directors was authorized to elect vice presidents and chairmen for those sections whose recommendations had not been received at the time of the meeting.

The Council elected Karl M. Wilbur to a 2-year term on the Nominating Committee.

Constitution and Bylaws

Upon recommendation of the Committee on Affiliation and Association, the Council voted to abolish the category of associate and to change the status of all societies listed as associates of the AAAS to the status of affiliates. The specific constitutional changes that were voted by Council were (i) to change the title of Article VIII from "Affiliates and Associates" to "Affiliated and Par-

ticipating Organizations"; (ii) to delete Section 3 of Article VIII; and (iii) to renumber Section 4 of Article VIII as Section 3.

Resolutions

Upon recommendation of the Interim Committee on the Social Aspects of Science, Council passed the following resolution:

"WHEREAS one of the purposes of the AAAS is 'to improve the effectiveness of science in the promotion of human welfare, and to increase public understanding and appreciation of the importance and promise of the methods of science in human progress'; and whereas the present rapid advance of science is accompanied by social problems of unprecedented magnitude that affect human welfare; therefore be it resolved that in recognition of the responsibility of scientists to participate in deliberations regarding the use made of new scientific knowledge, the Council of the AAAS authorizes the president to continue the work of this committee by appointing an enlarged group for the purpose of defining the problems, assembling the relevant facts, and suggesting a practical program, to be submitted to the AAAS Board of Directors, to implement the objectives of the AAAS in this regard."

Upon recommendation of the Committee on Resolutions, Council passed the two following resolutions:

"BE IT RESOLVED that the American Association for the Advancement of Science join with the National Academy of Sciences–National Research Council in the expression of admiration and sympathy for fellow-scientists in Hungary. Be it resolved further that the facilities of the AAAS and its affiliated societies be employed to aid in the placement of refugee Hungarian scientific and technical personnel and to render such other assistance as may be appropriate."

"The Council of the American Association for the Advancement of Science wishes to express its appreciation to the General Chairman and the members of the local committees, and to their institutions and organizations, for the highly effective work that resulted in the successful arrangements for the 123rd annual meeting."

Upon recommendation of the Committee on Resolutions, a resolution requesting the United States National Committee for the International Geophysical Year to seek means of cooperating with biologists in order that biological studies might be better represented in the program of the International Geophysical Year was returned to its authors with the suggestion that the resolution might better be submitted through the American Institute of Biological Sciences.

The Council decided not to endorse a resolution proposed by the Committee on Resolutions that dealt with the freedom of teaching and research and the effects upon such freedom of the large increases in college and university enrollments and the increased dependence of college and university research budgets on federal funds. Council voted to return the resolution to the committee with a request that it be reconsidered and submitted to the Board of Directors.

Financial Matters

The treasurer, Paul A. Scherer, reported that the Board of Directors had adopted the accompanying budget for the year 1957.

AAAS Operating Fund Budget, 1957: Receipts

Item		Estimated receipts
Dues of annual members		$315,000
Journal subscriptions		3,950
Members' special subscriptions, *Science* and *The Scientific Monthly*		23,000
Nonmember subscriptions		
Science	$48,000	
The Scientific Monthly	21,000	
		69,000
Miscellaneous Sales		
Science	1,600	
The Scientific Monthly	1,300	
		2,900
Advertising		
Science	230,000	
The Scientific Monthly	15,000	
		245,000
Sale of:		
Microcards	450	
Binders	1,600	
Symposium volumes	23,000	
Emblems	1,600	
Other sales	600	
		27,250
Meeting		
Registrations and program sales	7,500	
Program advertising	2,000	
Contributions	5,000	
Expositions		
Booth space	11,000	
Science library	1,200	
		26,700
Rental receipts		22,000
Income from investments		8,000
Cash discounts		400
Other receipts		200
Overhead		16,500
Total receipts		$759,900

The executive officer reported that preliminary estimates of income and expense figures for 1956 indicated that income would be perhaps $30,000 above the budgeted amount and that expenses would be in the neighborhood of $13,000 less than the budgeted amount. Income and expense for 1956 are expected to be in approximate balance. He also reported receipt during 1956 of the following gifts and grants:

$100,000 from the Carnegie Corporation of New York as the second year's portion of a $300,000 grant for a 3-year period to support the Association's Science Teaching Improvement Program;

$6000 from the Carnegie Corporation of New York to support a conference on the teaching of mathematics;

$65,000 from the National Science Foundation to support the Traveling Science Libraries;

$10,000 from the National Science Foundation for the Gordon Research Conferences for the purpose of bringing distinguished scientists from other countries to attend these conferences;

$5000 from members and friends as contributions to the Association's building fund;

$12,000 from the General Electric Educational and Charitable Foundation to aid in the Association's Science Teaching Improvement Program;

Approximately $14,000 from the estate of Margaret Young Smith;

$450 from C. M. Goethe of Sacramento, California.

The board reported that in compliance with a request made by the Council at its 1955 meeting, the question of assessing all affiliates $25 per year per Council member, in order to raise a fund from which Council members attending a meeting could be partially reimbursed for their traveling expenses, had been discussed with all affiliated societies. Since the reaction to the proposal had been predominantly negative, the board recommended that no further action be taken on the proposal. No action was taken.

Publications

The chairman of the Board of Directors, George Beadle, reported that the board, the Committee on Publications, the Board of Editors, and the Association's staff had studied the two journals *Science* and *The Scientific Monthly* and the possibility of merging those journals, and that the result of a series of discussions among these groups was the recommendation to merge the two journals into a single one that would retain the format of *Science*. Graham P. DuShane, editor, explained that the merger would be advantageous in that the editorial staff could concentrate on a single journal that he expected to be better than either of its predecessors, that the Association would send the same journal to all of its members, and that the wasteful duplication of material that must now be published in both would be avoided. The present character of *The Scientific Monthly*, he explained, would probably be retained in a special monthly issue of the new *Science*. The executive officer, Dael Wolfle, explained that the merger would in-

AAAS Operating Fund Budget, 1957: Expenses

Item	Estimated expenses per item	Estimated expenses (totals)	Limits on individual items
General administrative expenses			
Salaries	$190,000		$220,000
Insurance, retirement, and social security	12,850		14,500
Building maintenance	40,780		44,000
Interest on mortgage	7,300		7,400
Office supplies	18,000		20,000
Telephone and telegraph	3,000		3,800
Postage and freight	12,500		13,500
Travel	3,500		5,000
Miscellaneous	9,350		12,800
		$297,280	
Printing and manufacturing			
Science	260,000		275,000
The Scientific Monthly	63,000		66,000
Symposium volumes	22,000		27,000
Binders	1,200		1,500
Microcards	280		350
Emblems	500		1,200
		346,980	
Annual meeting			
Meeting and exposition	19,000		21,000
Press service	5,000		5,500
		24,000	
Sections, divisions, board, and committees			
Section expense	5,000		5,800
Division allowance	7,900		8,300
Board of directors	6,000		6,500
Editorial board	9,000		10,000
Other committees	5,000		6,000
		32,900	
Depreciation			
Building	23,200		
Furniture and equipment	6,000		
		29,200	
Advertising		54,000	64,000
Miscellaneous		300	
Executive officer's discretionary fund		5,000	
Contingencies and new activities		10,000	
Total operating expenses		$799,660	

crease publication costs and decrease revenue, and that the net change in financial position would amount to approximately $75,000 a year. Eventually, however, the merger should be financially profitable, for the larger circulation of the combined journal would make it a more attractive advertising medium and its improved quality would make it more attractive to prospective members. Because of the financial problems involved, the Board of Directors, in voting to approve the merger, did not specify the time at which it would become effective, but left the date for later determination.

Upon motion from the floor, Council voted to endorse the proposed merger of *Science* and *The Scientific Monthly*.

With respect to the year's record, the executive officer reported that the circulation of *Science* had increased by 3000 during 1956 and that the circulation of *The Scientific Monthly* had increased by 1400. A substantial portion of these increases was associated with a growth in membership of 2300 during the year. He also reported that Dr. DuShane, who had accepted appointment as editor on a trial basis at the beginning of 1956, had decided to remain with the Association on a permanent basis.

Affiliates

Upon recommendation of the Committee on Affiliation and Association, and with endorsement by the Board of Directors, Council voted to change the status of the American Institute of Biological Sciences from associate to affiliate and to elect the following eight organizations as affiliates: American Geological Institute, American Institute of Physics, Association for Computing Machinery, Cooper Ornithological Society, National Council of Teachers of Mathematics, Operations Research Society of America, Society for Economic Paleontologists and Mineralogists, Tau Beta Pi.

Other Business

John R. Mayor, director of the Association's Science Teaching Improvement Program, reported on the progress made in efforts to improve the teaching of science and mathematics and described some of the activities of the Science Teaching Improvement Program.

The executive officer reported the loss to the Association of the services of John A. Behnke, formerly associate administrative secretary, who resigned during 1956 to accept appointment as vice president of the Ronald Press Company.

Upon motion made from the floor, Council voted to authorize the Board of Directors to consider ways by which the interest of the past presidents of the AAAS may be maintained and their wisdom and experience utilized to the benefit of the Association.

DAEL WOLFLE

Executive Officer

Regional Consultants on Science and Mathematics Teaching

In order to meet more effectively the goals of the Science Teaching Improvement Program (STIP) of the American Association for the Advancement of Science during the coming year, a plan for regional consultants in science and mathematics to serve colleges and universities has been established. The consultants will be available for visits to colleges and universities in their areas upon invitation by the institutions. In accepting responsibility for this work, the 20 consultants will actually be additions (without compensation) to the staff of STIP, which will pay travel expenses and a small allowance for secretarial help. The schedule of visits will be the responsibility of each consultant. This regional consultant service has been made possible by a grant to AAAS from the General Electric Educational and Charitable Fund.

STIP is an active program to increase the number of well-qualified science and mathematics teachers at the secondary-school level. In order to carry out STIP, the cooperation of scientists in all parts of the country must be obtained. Success will depend, to a considerable degree, on decisions and activities on a local basis. During the first year of operation, representatives of STIP presented the program to scientists on 50 college and university campuses, in state and regional meetings called by STIP, and at meetings of 12 state academies of science as well as of other professional scientific societies. In these travels many good suggestions were obtained; counsel was given on the development of local projects, and cooperation was sought in the attainment of STIP objectives.

The frequent suggestions that visits to a campus from a representative of a national scientific society can be of value in the stimulation of local activity has resulted in the project for regional consultants. In calls on colleges and universities the consultants might: (i) meet with staff members in education and science jointly to consider problems of science and mathematics teacher education; it would be desirable in these conferences if at least one representative of the state department of education

could also be present, and possibly also secondary-school teachers; (ii) suggest ways in which colleges and universities might maintain closer working relationships with science and mathematics teachers in secondary schools; (iii) review possibilities for achieving greater awareness of the need for strong programs in science and mathematics, on the part of the general public, school boards, and school administrators; (iv) take part in the discussion of programs to interest more young people in the study of science and mathematics and the preparation for careers in science, engineering, and teaching; (v) seek information about promising programs which can be shared with other consultants and with the STIP office; (vi) discuss ways in which the AAAS, through STIP and other activities, may be of assistance in the improvement of science teaching.

The regional consultants for various areas are the following: *New England*, selection to be made by American Academy of Arts and Sciences; *New York*, Lowell D. Uhler (biology), Cornell University; *Pennsylvania, New Jersey*, Marsh White (physics), Pennsylvania State University; *Virginia, West Virginia*, E. J. McShane (mathematics), University of Virginia; *Maryland, Delaware, District of Columbia*, I. E. Wallen (zoology), assistant director, STIP (on leave from Oklahoma A&M College); *North Carolina, South Carolina*, Walter M. Nielsen (physics), Duke University; *Georgia, Alabama, Florida*, Russell H. Johnsen (chemistry), Florida State University; *Ohio, Michigan, Indiana*, A. B. Garrett (chemistry), Ohio State University; *Wisconsin, Minnesota*, Kenneth O. May (mathematics), Carleton College; *Illinois, Missouri, Iowa*, Jerry J. Kollros (zoology), State University of Iowa; *Kentucky, Tennessee*, F. Lynwood Wren (mathematics), George Peabody College for Teachers; *Mississippi, Arkansas, Louisiana*, Houston Karnes (mathematics), Louisiana State University; *Nebraska, Kansas*, G. Baley Price (mathematics), University of Kansas; *Montana, North Dakota, South Dakota*, Adrien L. Hess (mathematics), Montana State College; *Oklahoma, Texas*, Joe P. Harris, Jr. (biology), Southern Methodist University; *Colorado, Wyoming*, Burton W. Jones (mathematics), University of Colorado; *New Mexico, Arizona*, M. G. Seeley (chemistry), University of Arizona; *Utah, Nevada*, Melvin C. Cannon (chemistry), Utah State Agricultural College; *Washington, Oregon, Idaho*, E. G. Ebbighausen (physics), University of Oregon; *California*, Norman A. Watson (physics), University of California (Los Angeles).

JOHN R. MAYOR
AAAS Science Teaching Improvement Program

BOOK REVIEWS

The Evolution of Human Nature. C. Judson Herrick. University of Texas Press, Austin, 1956. 506 pp. Illus. $7.50.

In *The Evolution of Human Nature* C. Judson Herrick, the dean of basic neurology in this country, has given us the distilled wisdom of more than 60 years of teaching and research in the nervous system. He has contributed largely to the detailed anatomy of the amphibian nervous system. More than that, he has looked at the components of the nervous system with the eye of understanding. He has seen in the necessary relatednesses of the neuronal components the synthesis of the whole, which is more than the sum of its parts.

This book is a must. It should be read by everyone who is interested in human behavior and particularly by those whose major interest is the nervous system. There are so many quotable sentences in the book that one is tempted to select a number of them. This would defeat the purpose of a review, for the sentences must be read in context. It is difficult to do justice to the work, for it is one of the real contributions to our day and generation.

The theme of the book is clear and runs somewhat as follows. It must be understood, of course, that this is the thinnest of outlines—a skeleton that can only be appreciated when clothed in Herrick's beautiful exposition. It begins with the basic assumption that the universe is a place of law and order. One of the exciting enterprises of the mind of man is to search for that order and to define the laws that establish it. Beginning with raw protoplasm, we are reminded that the four fundamental properties of protoplasm—excitation, propagation, integration, and reaction—are the essential properties of the nervous system which, through the long story of evolution, has increased in efficiency to the point where, in the nervous system of man, the living organism is provided with the abilty to dominate its environment—in fact, not only to dominate it, but to create it.

The first stage in this increased efficiency apparently is the appearance of neural mechanisms with increased capacity to analyze external and internal excitations. These, however, would be useless without a greater speed of propagation, a greater facility in integrating the results of analysis, and a more effective reaction system. Living things, with these added, differentiated nervous mechanisms, could adjust to much more complex circumstances and, therefore, stood better chance of survival. But the evolution story did not stop there. Instead, living systems appeared with greatly increased numbers of neuronal components. This provided a greater sensitivity to the environment and a greater success in adjusting to it.

Finally, there appeared living systems—man—with the nervous system composed of an incredible number of neuronal components, some 10 billion in the cortex alone. As always, with an increasing complexity and much greater numbers, new qualitative attributes appeared as a result of the necessary relationships of the entities. Each of these new qualities defined the unique wholeness of each class of living systems. There appeared two almost unique properties of the incredibly complex nervous system of man. On top of stereotyped automatic behavior and the increasing expertness of analysis and also, probably as a result of an enormous increase of the numbers of cells, a very real discriminatory power appears. This has enabled man to relate sharply analyzable excitations in an incredibly complex manner. Great competence in visual and auditory and other sensory stimulations has resulted. This sort of thing is a major miracle, but it is overshadowed by the most unique of all the properties of the human nervous system. This is the ability of neurones to synthesize symbols out of sharply analyzed excitations and widely discriminated stimuli. These symbols can stand for a whole galaxy of excitations which constitute what we think of as ideas or concepts. As a result, an idea becomes just as adequate an excitation to the human nervous system as does a flash of light or the sound of a musical instrument. Not only are ideas adequate stimuli, but their consequences are far more explosive than any nuclear reaction known to man. These highly efficient attributes of the nervous system would, of course, be useless were it not for the fact that, built upon phylogenetically old reaction systems, new and incredibly varied motor patterns appeared. Perhaps the most important of these is the very effective use of the hand.

So in man the nervous system has appeared as a beautifully organized and patterned linking and chaining of neurones, endowing him with a unique individuality such that no two human beings are alike. As one looks at the long story of evolution, it would appear that the process of growth and differentiation has had direction—that it has been directed, in fact, toward the appearance of the unique human being. It follows from this that ideas

become the most important as well as the most dangerous of all excitations of the nervous system. Witness, in fact, the domination of man over his physical environment, the product of his creative imagination, or his capacity to see new and unexpected relatednesses in the world about him and to synthesize these into new concepts. But each nervous system is different from all others, and our real problem is to discover the synthesizing capacities of the mind of the individual and, through practice and experience, realize its full potentialities. Needless to say, this involves value judgments, one of the most mooted questions in modern thought. It would seem clear from Herrick's presentation that he has provided a valid basis and valid judgment. That which is true is good; that which is wrong is bad. Since, however, we do not know all the truth, moral judgments, which in man's experience have seemed for the time correct, must hold sway until we know better. As our understanding of truth enlarges, man-made moral judgments must be modified by the values established through our greater knowledge of the natural law.

The Evolution of Human Nature is a superb book, exhibiting unrivaled knowledge and wisdom. One can only wish that in the epilogue Herrick had provided us with a little more cogent expression of his faith.

H. S. Burr

Yale University School of Medicine

The Historical Background of Chemistry. Henry M. Leicester. Wiley, New York; Chapman and Hall, London, 1956. 260 pp. Illus. $6.

This is a short book on a big subject. But it was not the author's intention to provide a comprehensive history; that must be the task of "many men with different training and viewpoints." However, Leicester has produced a generally effective synopsis of the main lines in the development of chemical thought and discovery from prehistoric times to the present day—in short, a *Historical Background of Chemistry*. He has placed his "main emphasis on the development and interrelation of chemical concepts." His style is quite readable, and the chapters are short and efficiently written.

But a short book must necessarily emphasize certain areas at the expense of others. Leicester has chosen to place his emphasis on the pre-Lavoisier period in order to refute those who "have felt that only after the time of Boyle and Lavoisier could chemistry have a real history." In this task he has been successful. The roots of chemical ideas are deep in the past, and Leicester has traced them clearly and accurately. By discussing it in a separate chapter, he places much needed emphasis on the technical advances of the 16th century, which contributed so much to the character of what we call modern chemistry. He also similarly isolates the revival and spread of atomistic theories in the 17th century.

He makes one departure from his general adherence to continuity of development by including a chapter on Chinese alchemy. Although this seems to be customary in general histories of chemistry, Leicester admits that Chinese and Western alchemy were probably independent of one another. In so short a book, the value of including Chinese alchemy seems questionable.

The last half of the book, which deals with the post-Lavoisier years, is not as well done as the first half. The treatment is too brief to do justice to the flood of significant developments that took place during the 19th and early 20th centuries. For example, the chapter on atomic and molecular weights and the periodic law is about the same length as the earlier chapter on phlogiston. In general, the faults of his treatment of the last 160 years are those of omission.

He also fails to make much of the logical relationship of Dalton's atomic theory to the operational definition of the element as earlier given by Lavoisier. The atomic theory served to focus attention on the atomic weight relationships of the elements, and it by-passed the philosophic problem of how to determine finally which substances are truly elementary. Leicester's preservation of the erroneous idea that Davy proved the elementary nature of chlorine (p. 161) reflects the same neglect of this phase of early 19th century problems. Davy never fully accepted the elementary nature of any substance, and his reluctance illustrates the basic problem of his time.

Leicester includes a short but effective chapter on the development of chemistry as a profession during the 19th century, a welcome addition to the contents of a history of chemistry. But in more recent years, particularly since World War II, science and society have moved into closer and more obvious relations with one another, chiefly through the increased governmental sponsorship of research in all countries. It is to be regretted that the author did not devote one of his brief chapters to raising some of the problems associated with this development.

The teacher using this book as a textbook will find it to be an excellent outline. But he will have to supply for his class the details which the author has omitted, and particularly the human aspects

which can bring the student personally into the great human enterprise we call science.

ROBERT SIEGFRIED

University of Arkansas

Hailstorms of the United States. S. D. Flora. University of Oklahoma Press, Norman, 1956. xiii + 201 pp. Illus. $3.50.

S. D. Flora, for 32 years section director of the U. S. Weather Bureau for Kansas, has, since his official retirement, written the distinctly successful *Tornadoes of the United States* (1953) and here considers storms which cause much more destruction of property in the United States than do tornadoes. He presents a panoramic view of what hailstorms are and have done, the colossal toll they take of crops and livestock, and the damage they cause to homes and other buildings, especially those with much glass. Even metal-topped automobiles are often seriously damaged, since hailstones as large as golf balls are not very rare, and stones as large as baseballs are occasional. This book also tells of hail forecasting and the development of protective insurance. Considered also are the numerous types of efforts to reduce hailstorm damage.

With the help of maps, the distribution over the United States of hailstorm frequency in various seasons is presented. Much of the volume consists of a state-by-state discussion of hailstorm frequency and damage. For each area, some especially damaging hailstorms are listed with estimates of the damage done. A separate chapter is devoted to "The most destructive hailstorms of the United States" and another to "Hailstorms in other countries." In the latter, evidence is presented of the great destruction occasionally caused in other parts of the world, including even the tropics, and the considerable number of people who have been killed as a result of severe bruising inflicted during hailstorms. In part of India 246 people were killed in 1 day. Insurance against hailstorms, the most effective way by which an individual property owner can obtain relief, is helpfully discussed.

This book is unique in its presentation of information concerning hailstorms and is authoritative, well-written, and attractively published. It will help greatly to lead those who read it to appreciate more deeply one meteorological hazard to man's daily efforts to make a living in the United States. It is worthy of wide reading. A copy should be in all sizable libraries and in most school libraries.

STEPHEN S. VISHER

Indiana University

Earth Satellites. Patrick Moore. Norton, New York, 1956. 157 pp. Illus. $2.95.

This little book makes delightful reading. The subject, which concerns man's preparations for venturing out into space, is a fascinating, exciting, and challenging one that can easily lead into the realm of fantasy. Yet the author avoids this pitfall and succeeds in maintaining just the right balance between the pioneering speculation that gets new things started and the sober, realistic appraisal of the practical problems involved that gets them accomplished. The author's style is fluid and pleasing; the illustrations are clear, informative, and occasionally amusing; and the type is extremely clear and easy on the eye.

The book opens with the White House announcement of the United States satellite program for the International Geophysical Year. The author then provides some background material on high-altitude research, the upper atmosphere, and rockets. After a brief review of early plans for and thoughts about orbital vehicles, he then proceeds to discuss Project Vanguard and the researches that can be done with unmanned artificial earth satellites. The author then concludes with a very interesting discussion of manned satellites and flight out into space.

There are a few specific points I should like to mention. On page 89 the author places the end of the International Geophysical Year at July 1958; this is an error, since the IGY will run until the end of December 1958 and will, therefore, really be a year and a half. On page 30, it is stated that solid propellants are still unreliable for high-altitude research. Whereas this probably would have been a correct statement a number of years ago, I do not believe it is true now. Proof of my contention rests in the fact that more solid-propellant rockets are now fired per year for upper-air research than liquid-propellant vehicles, there are more solid-propellant rockets on schedule for the IGY than liquid ones, and the major emphasis in the development of new high-altitude sounding vehicles now is on solid propellants.

On page 78, in discussing the third step of the Vanguard launching vehicle, the author says that "it too may become a 'satellite.' " I do not feel that the author has made it sufficiently clear that if the artificial satellite is successfully placed in a stable orbit about the earth, then necessarily the third stage of the rocket will also be a satellite. This is because the third stage, in pushing the scientific satellite into its orbit, will move right along with it into the same orbit. Then they will be separated at only a few feet per second relative velocity, so

that they will both continue to revolve about the earth.

On page 90 the author compares the vertical sounding rocket with an orbiting satellite as a research vehicle. He states that "researches with normal rockets can never be very satisfactory" and that "the orbital vehicle is vastly superior." His reason is mainly that the orbital vehicle will permit observations over very long periods of time, whereas the conventional sounding rocket provides only a short time for observations. This analysis is, I believe, quite superficial. It is true that the long period of observation provided by an orbiting satellite is a valuable feature. But a satellite coursing along a stable orbit must necessarily be traveling above virtually all of the atmosphere and will, therefore, usually be no better than ground-based observatories for studying events occurring within the atmosphere. A vertical sounding rocket that traverses the different altitude levels in the atmosphere is needed to measure densities, pressures, temperatures, ionization, composition, airglow intensities, winds, current densities, and the like as functions of height; satellite-borne equipment cannot do it. Although satellite-borne instruments can monitor electromagnetic and particle radiations as they exist outside the atmosphere, nevertheless a vertically launched rocket is needed to determine at what levels and in what quantities these radiations are absorbed in the air and to determine precisely what effects they cause in being absorbed. Finally, for the cost of building, instrumenting, launching, and observing one satellite, a tremendous amount of vertical sounding can be done, and this could offset considerably the advantage that the orbital vehicle has of being on orbit for a long period of time.

The author also does not give the proper impression with regard to recovery of instruments from a sounding rocket. Whereas it is true that there is always a risk of not being able to retrieve film, specimens, or other items after a rocket flight, nevertheless recovery methods, including the use of parachutes, have now been developed to the point where failure to recover the desired item is the exception rather than the rule.

On page 102, the author asks, "Can it (the orbital satellite), too, be adapted for warlike purposes?" In reply he says, " . . . the answer seems to be a rather decisive 'no.' " In this I agree heartily. It is my conviction that artificial satellites and space stations will lend themselves far more easily to peacetime pursuits, such as monitoring the weather, and to scientific research than they will to military purposes.

Having aired my differences with the author on a few points, let me now hasten to repeat my recommendation of this book. *Earth Satellites* by Patrick Moore is well written, informative, and stimulating. Spend an evening with it. It is truly "out of this world."

HOMER E. NEWELL, JR.
Naval Research Laboratory

Things Maps Don't Tell Us. An adventure into map interpretation. Armin K. Lobeck. Macmillan, New York, 1956. 159 pp. Illus. $4.95.

For more than three decades, A. K. Lobeck's physiographic diagrams and laboratory exercises have aided college students in understanding the mysteries and wonders of the physical landscape. Now retired from the academic field (Columbia and Wisconsin), Lobeck is directing his mastery of physiography and his artistic draftsmanship toward a larger audience.

In *Things Maps Don't Tell Us* he presents, for the nontechnical layman, explanations for some 70 interesting land forms selected from all parts of the world. The technique employed is a simple one that makes effective use of Lobeck's skills in graphic presentation and clear, concise exposition.

"On the Left-hand pages of this book," the author explains, "I am setting before you a *problem* in the form of a simple map. This map shows a few geographical details which I have taken from one of the maps, atlases, or road maps that you yourselves are likely to have at hand. I have also called attention in the accompanying text to a few of the details of the map which it would be well to puzzle over a bit before referring to the page on the Right to see what the *explanation* actually is." "Thus," he continues, "I hope your curiosity will be piqued and you may be brought to wonder why things have come to be as they are. You will be right, too, if you come to the conclusion that there is a meaning for almost every fact represented on the map, tens of thousands of them, and not only the few score which are presented in this book."

Most of the "few score" features illustrated in the book are associated with coast lines, islands, rivers, and lakes. The explanations for the land forms pictured, however, embrace virtually every type and process of erosion and deposition. Nonetheless, one has the feeling that there is much more information that the author is anxious to impart. He excites the curiosity of the reader in a final chapter which lists "more unanswered problems," such as peculiarities of boundaries, locations of cit-

ies and towns, and the fascinating stories behind the names on the map.

This is a book on map *interpretation* rather than map *reading*. The former, Lobeck observes, is much more than locating a place on a map. "Map interpretation [rather] is like the process of reading between the lines of a story whereby the reader draws certain inferences and conclusions which the author did not specifically make."

A journey through *Things Maps Don't Tell Us* should be a delightful and profitable experience for all who love maps as well as for the amateur or professional outdoor enthusiast. Many readers of the book will agree with the author that "to be awed merely by the fantastic aspects of a scene without any deeper understanding is . . . only a form of shallow satisfaction unworthy of any real lover of nature."

WALTER W. RISTOW

Library of Congress

Theory and Dynamics of Grassland Agriculture. Jack R. Harlan. Van Nostrand, Princeton, N.J., 1956. 281 pp. Illus. + plates. $6.75.

Grassland farming is by far the most intellectually demanding branch of agriculture. A basic knowledge of almost all sciences is required to understand how the three partly controllable variables—soil, plants, and animals—interact under the impact of a fourth, notoriously changing but uncontrollable factor: the climate.

In this book Jack Harlan has brought together pertinent chapters from climatology, pedology, plant taxonomy, physiology and ecology, and animal nutrition which should enable the student to analyze the complexities of grassland agriculture. It is an indictment of modern trends in education, rather than of Harlan's erudition, that he has had to spend so much time on *prima principia* that the synthesis has received less attention than it deserves. And yet in grassland farming the interaction among soil, plants, and animals is much more important than the sum of the three. Since Harlan is not an animal specialist, it is particularly the animal's reactions to its environment that have suffered most under this treatment.

However, Harlan's book will, without doubt, go a long way toward stimulating the development of that rare, but desirable hybrid, the soil-plant-animal man, as opposed to the modern product who specializes in an ever-narrowing field.

JOHN HANCOCK

International Bank for Reconstruction and Development

Calder Hall. The story of Britain's first atomic power station. Kenneth Jay. Harcourt, Brace, New York, 1956. 88 pp. Illus. $3.

The generation of electric power on an industrial scale from the Calder Hall nuclear power station is indeed an important event in the industrial history of the world. The fact that the British are proud of this project is very evident both in Kenneth Jay's text and in the foreword by Edwin Plowden.

Calder Hall is primarily a historical account of events and considerations leading to the Calder Hall nuclear power station. The basic principles of nuclear reactor design are treated in a very general and elementary fashion to provide a basis for the primary text. Brief attention is also given to reactor types other than that of Calder Hall as they relate to the over-all nuclear power program of the United Kingdom.

The Calder Hall reactors, one of which is now in operation, are intended primarily for the production of military plutonium and secondarily for power production. It is pointed out, however, that the plutonium could "be used later to fuel enriched reactors of more advanced design and so help to achieve a better overall utilization of uranium." The reactors are fueled with natural uranium clad in a magnesium alloy and arranged vertically in the core. Heat is removed by carbon dioxide under a pressure of about 7 atmospheres. Graphite serves as the neutron moderator. The recitation of factors leading to major design decisions is of historical interest and provides positive examples of problems typical of those being faced by groups engaged in nuclear power reactor projects of various kinds in different parts of the world.

In view of continuing discussions in the United States with respect to dual-purpose reactors, it is of interest to note comments regarding optimization of the design for plutonium production. These changes resulted in poorer steam conditions and in an increase in capital cost of the steam plant and turbines for a given electric output. Each Calder Hall reactor is described as capable of operation at about 200,000 kilowatts of heat. A plant, consisting of two reactors, will provide a maximum output of 92,000 kilowatts of electricity. Part of the electricity is required to supply the plant itself, leaving a net output of 60,000 to 65,000 kilowatts for the national grid.

A liberal selection of sketches and photographs helps to provide an improved basis for general appreciation and understanding of the plant arrangement and some of the construction problems. It is understandable that much of the detailed attention

is given to construction problems in view of the very limited operating experience available at the time of writing. It is also understandable that the design information on vital parts of the reactor system is quite general. A reader expecting to find detailed performance and design information that might be used for purposes of comparing the gas-cooled, Calder Hall type, nuclear power reactor with other types of reactors will be disappointed. It is stated that plants of this type, when optimized for power production, are expected to make electric power for 0.6 pence (about 7 mills) per kilowatt hour. No basis is given for this estimate, nor is any estimate given for the reactor that is now in operation.

The text is written for understanding by persons with little, if any, background in nuclear technology. It is likely to be interesting to those seeking historical background and a general acquaintance with the nature of the problems in building nuclear power plants. It will not be very useful to the technician, engineer, or scientist who is now active in the nuclear power field and who is seeking technology to aid in his evaluation or design problems.

The ultimate future of gas-cooled reactors and, in fact, of reactors of any type, will depend on the operating experience and research results, which are expected to lead to improvements and lower costs. In that sense, the story leading to the start-up of a single Calder Hall reactor, significant as it is, leaves me with a feeling that the most important part of the story is yet to be written. On the other hand, history must be written in parts as events occur, and this part is now recorded and waiting to be fitted into the larger picture.

U. M. Staebler

U.S. Atomic Energy Commission

Botanical Exploration of the Trans-Mississippi West, 1790–1850. Susan D. McKelvey, Arnold Arboretum, Jamaica Plains, Mass. 1955. xl + 1144 pp. Maps. $25.

Only one book of its kind is expected in a century. Days without time are needed to gather the facts. Nor is compilation alone the making of the book, for only a careful knitting of the skeins of facts will present a finished work. McKelvey's tome is both a readable, though hardly a lap-weight (5 pounds, 14 ounces), history and reference work of the very first importance. It will "hit" the A. L. A. list of recommended reference books for all serious libraries. Museums and workers in natural history, in both botanical and zoological fields, will find the book of constant reference value. Nor will they be disappointed for the finer points of documentation and careful quotation. The excellent maps, nine in the text and two large folding maps in the pocket, carry the routes and place names associated with the various explorers; they are the work of the well-known cartographer of Harvard, Erwin Raisz. Altogether the book is a monument, first, to the author's zeal and persistence, then to the publisher's vision and to the skills of the editors, the mapmaker, the compositors, and printers. Incidentally, the price, far from netting an income for the publisher, will only slowly recover production costs defrayed by a now exhausted revolving fund for special publications set up by a patron of the Arnold Arboretum.

Although the person who turns to McKelvey in pursuit of some fact to clear away a taxonomic puzzle or amplify some historic perspective will likely find his answer, it will be circuitously. He may stumble over long and often anecdotal footnotes. This will delay him, but in the end will prove more of a pleasure than a mishap. Testy bits of philosophy are mortised between the tenons of fact. Here and there the thrill of the historian's hunt, too, is often shared with the reader, and this may range from correspondence with Perle Mesta on the identity of Karl Friedrich Mersch to Grace Nute for her special knowledge of Lamare-Picquot, an all-but-unknown Frenchman who visited Minnesota and Missouri. For the historian devoted to Western Americana—Mississippi River to the Pacific—and for the historically minded biologist, Susan McKelvey's opus is thick and rich. As a compendium of our knowledge of the lives and travels of botanical explorers (who were often also engaged in collecting insects, birds, or other "natural curiosities") this book ". . . is not a dull enumeration of facts. It might also be compared to the best type of fiction, were it not better still, were it not reality."

Joseph Ewan

Tulane University

The Earth Beneath Us. H. H. Swinnerton. Little, Brown, 1st American ed., Boston, 1956. 335 pp. Illus. $5.

This is the first American edition of a new book by H. H. Swinnerton, professor emeritus at the University of Nottingham, England. This is an attempt to bring the science of geology before the general public in a readable and entertaining manner. It does not presuppose any knowledge of the

subject but assumes that the reader has a natural curiosity about the earth on which he lives.

After a few short chapters on the origin of the earth, Swinnerton describes the various features that make up the surface of the earth. The formation of mountains, the causes of earthquakes, the accumulations of underground water, and the formation of caves are a few of the subjects discussed in the seven chapters of this section. The section ends with a discussion of the geologic time scale.

The author next discusses "The realms of Pluto," in which he tells of the presence of granite, basalt, and other igneous rocks within the earth. Some attention is paid to the origin of ores. The next section is entitled "The climates of the past." Here various arid and glacial climates of the geologic record are discussed. No attempt is made to treat the various climates in a chronological order, which may make the section a little difficult for the nongeologic reader to follow; however, the examples given are very interesting and cover a wide geographic area.

The last two sections concern the life of the past with the final chapters devoted to the "Coming of man." Some readers may be disturbed because the treatment does not follow "standard" biological order, but one cannot help but be interested in the well-chosen examples of the different groups of animals discussed by Swinnerton.

As might be expected, many of the examples cited in the book are concerned with the British Isles, but Swinnerton is by no means restricted in his observations, which come from all parts of the world, many from the United States. The book is illustrated with 28 sketches, which, although not as numerous as in certain other books on the same subject, do serve as an admirable supplement to the clearly written text.

HORACE G. RICHARDS
University of Pennsylvania and
Academy of Natural Sciences

Books Reviewed in SCIENCE

4 January

Evolution: the Ages and Tomorrow, G. M. McKinley (Ronald). Reviewed by E. O. Dodson.

Dermatology, D. M. Pillsbury, W. B. Shelley, A. M. Kligman (Saunders). Reviewed by L. H. Warren.

Treatise on Inorganic Chemistry. vol. II, *Sub-Groups of the Periodic Table and General Topics,* H. Remy (Elsevier). Reviewed by R. Gilchrist.

Exploration for Nuclear Raw Materials, R. D. Nininger, Ed. (Van Nostrand). Reviewed by E. W. Berry.

Travels and Traditions of Waterfowl, H. A. Hochbaum (University of Minnesota Press). Reviewed by F. C. Lincoln.

Electricité, Y. Rocard (Masson). Reviewed by V. A. Johnson.

The World of Learning, 1956 (Europa Publications). Reviewed by D. Wolfle.

Rayonnements de Particules Atomiques, Electrons et Photons, A. Berthelot (Masson). Reviewed by L. Marton.

11 January

A Study of Thinking, J. S. Bruner, J. J. Goodnow, G. A. Austin (Wiley). Reviewed by D. A. Riley.

S. P. Botkin and the Neurogenic Theory of Medicine, L. R. Borodulin (State Publishing House of Medical Literature). Reviewed by S. A. Corson.

Cours de Physique Générale: Electricité, G. Goudet (Masson). Reviewed by I. Estermann.

Parasites and Parasitism, T. W. M. Cameron (Methuen). Reviewed by C. G. Huff.

Geology and Ourselves, F. H. Edmunds (Philosophical Library). Reviewed by R. C. Stephenson.

Educating Spastic Children, F. E. Schonell (Philosophical Library). Reviewed by W. M. Phelps.

18 January

Man's Role in Changing the Face of the Earth, W. L. Thomas, Jr., Ed. (University of Chicago Press). Reviewed by B. T. Dickson.

Engineering as a Career, R. J. Smith (McGraw-Hill). Reviewed by H. H. Armsby.

The American Experiences of Swedish Students, F. D. Scott (University of Minnesota Press). Reviewed by S. Lysgaard.

Engineering Mathematics, K. S. Miller (Rinehart). Reviewed by M. E. Shanks.

25 January

Rattlesnakes, L. M. Klauber (University of California Press). Reviewed by C. H. Pope.

Solid State Physics, vol 2, F. Seitz and D. Turnbull, Eds. (Academic). Reviewed by R. K. Wangsness.

Chemistry and Uses of Pesticides, E. R. de Ong (Reinhold). Reviewed by E. L. Green.

Handbuch der Physik. vol. XXXVI, *Atome II,* S. Flügge, Ed. (Springer). Reviewed by F. Reines.

Ninth Annual Report of the Advisory Council on Scientific Policy 1955–1956 (H. M. Stationery Office).

Inhaltsstoffe und Prüfungsmethoden Homöopathisch Verwendeter Heilpflanzen, H. Schindler (Editio Cantor). Reviewed by E. H. Lucas.

New Books

Atomic Weapons and East-West Relations. P. M. S. Blackett. Cambridge University Press, New York, 1956. 107 pp. $2.

Men with Golden Hands. A book of surgical miracles. E. H. G. Lutz. Translated by W. H. Johnson. Appleton-Century-Crofts, New York, 1956. 269 pp. $3.75.

Personal Character and Cultural Milieu. A collection of readings. Compiled and edited by Douglas G. Haring. Syracuse University Press, Syracuse, N. Y., rev. ed. 3, 1956. 834 pp. $7.50.

Composition and Properties of Concrete. George E. Troxell and Harmer E. Davis. With chapters on "Proportioning of concrete mixtures" and "Strength of concrete" by J. W. Kelly. McGraw-Hill, New York, 1956. 434 pp. $7.75.

Organo-Metallic Compounds. G. E. Coates. Methuen, London; Wiley, New York, 1956. 197 pp. $2.50.

Synthetic Polypeptides. Preparation, structure and properties. C. H. Bamford, A. Elliott, W. E. Hanby. Academic Press, New York, 1956. 445 pp. $10.

Chemical Process Economics in Practice. J. James Hur, Ed. Reinhold, New York; Chapman & Hall, London, 1956. 115 pp. $3.95.

The Person behind the Disease. Julius Bauer. Grune & Stratton, New York, 1956. 136 pp.

Your Child's Speech. A practical guide for parents for the first five years. Flora R. Schreiber. Putnam's, New York, 1956. 256 pp. $3.50.

The Reactive Intermediates of Organic Chemistry. John E. Leffler. Interscience, New York, 1956. 275 pp. $6.

The Psychology of Sex Offenders. Albert Ellis and Ralph Brancale. Thomas, Springfield, Ill., 1956. 132 pp. $3.75.

Modern Instruments in Chemical Analysis. Frank M. Biffen and William Seaman. McGraw-Hill, New York, 1956. 333 pp. $7.50.

Man of High Fidelity: Edwin Howard Armstrong. Lawrence Lessing. Lippincott, Philadelphia, 1956. 320 pp. $5.

Atomic Energy for Your Business. Today's key to tomorrow's profit. Arnold Kramish and Eugene M. Zuckert. McKay, New York, 1956. 269 pp. $3.95.

Lehrbuch der Tropenkrankheiten. Ernst G. Nauck. Thieme, Stuttgart, 1956. (order from Intercontinental Medical Book Corp., New York 16). 432 pp. $15.25.

The Compleat Cruiser. The art, practice and enjoyment of boating. L. Francis Herreshoff. Sheridan House, New York, 1956. 372 pp. $5.

Organic Syntheses. An annual publication of satisfactory methods for the preparation of organic chemicals. vol. 36. N.J. Leonard, Ed. Wiley, New York; Chapman & Hall, London, 1956. 120 pp. $3.75.

Phase Diagrams in Metallurgy. Their development and application. Frederick N. Rhines. McGraw-Hill, New York, 1956. 340 pp. $12.

The Study of Plant Communities. An introduction to plant ecology. Henry J. Costing. Freeman, San Francisco, ed. 2, 1956. 440 pp. $6.

International Review of Cytology. vol. V. G. H. Bourne and J. F. Danielli, Eds. Academic Press, New York, 1956. 570 pp. $11.50.

Stormy Life. Memoirs of a pioneer of the air age. Ernst Heinkel. Jürgen Thorwald, Ed. Dutton, New York, 1956. 256 pp. $5.

Wing Theory. A. Robinson and J. A. Laurmann. Cambridge University Press, London, 1956 (order from Cambridge University Press, 32 East 57th Street, New York). 569 pp. $13.50.

History of Analytic Geometry. Scripta Mathematica Studies, Nos. 6 and 7. Carl B. Boyer. Scripta Mathematica, Yeshiva University, New York, 1956. 291 pp. $6.

Strahlendosis und Strahlenwirkung. Tafeln und Erlauterungen unterlagen fur den strahlenschutz. B. Rajewsky. Thieme, Stuttgart, 1956 (order from Intercontinental Medical Book Corp., New York 16). 486 pp. $8.60.

Rheology. Theory and Applications. vol. 1. Frederick R. Eirich. Academic Press, New York, 1956. 761 pp. $20.

Biological Treatment of Sewage and Industrial Wastes. vol. I, *Aerobic Oxidation*. Brother Joseph McCabe and W. W. Eckenfelder, Jr., Eds. Reinhold, New York; Chapman & Hall, London, 1956. 393 pp. $10.

Tables of Physical and Chemical Constants and Some Mathematical Functions. Originally compiled by G. W. C. Kaye and T. H. Laby. Prepared under the direction of an editorial committee. Longmans, Green, New York, ed. 11, 1956. 233 pp. $5.

English Translation of the Bulletin of the Academy of Sciences of the USSR. Physical Series. vol. 19, No. 5. Columbia Technical Translations, White Plains, N. Y., 1956. 109 pp. $20.

Theory of Approximation. N. I. Achieser. Translated by Charles J. Hyman. Ungar, New York, 1956. 307 pp. $8.50.

Descriptive Geometry. College Outline Series. Steve M. Slaby. Barnes & Noble, New York, 1956. 353 pp. $2.25.

Biological Sciences. Series VI. *Progress in Nuclear Energy*. J. C. Bugher, J. Coursaget, J. F. Loutit. McGraw-Hill, New York; Pergamon, London, 1956. 205 pp. $7.

The Land Called Me. An autobiography. E. John Russell. Allen & Unwin, London, 1956. 286 pp. $5.75.

Indian Students on an American Campus. Richard D. Lambert and Marvin Bressler. University of Minnesota Press, Minneapolis, 1956. 122 pp. $3.

An Encyclopaedia of the Iron and Steel Industry. Compiled by A. K. Osborne. Philosophical Library, New York, 1956. 558 pp. $25.

Separation and Purification. vol. III, pt. 1 of *Technique of Organic Chemistry*. Arnold Weissberger, Ed. Interscience, New York, ed. 2, 1956. 873 pp. $17.50.

Physiologie de l'Insecte. Le comportement, les grandes fonctions ecophysiologie. Rémy Chauvin. Institut National de la Recherche Agronomique, Paris, ed. 2, 1956. 917 pp. $9.50.

The Chemistry and Technology of Leather. vol. I, *Preparation for Tannage*. Fred O'Flaherty, William T. Roddy, Robert M. Lollar. Reinhold, New York; Chapman & Hall, London, 1956. 495 pp.

Beiträge zur Geschichte der Erkenntnis des Erdmagnetismus. Heinz Balmer. Sauerlander, Aarau, Switzerland, 1956. 892 pp. F. 31.10.

Ancestors and Immigrants. A changing New England tradition. Barbara M. Solomon. Harvard University Press, Cambridge, 1956. 276 pp. $4.75.

Hi-Fi from Microphone to Ear. Modern sound-recording and reproduction technique. G. Slot. Philips Technical Library, Eindhoven, Netherlands, 1956. 169 pp.

Trigonometry Refresher for Technical Men. A. Albert Klaf. Dover, New York, 1956 (unaltered republication of ed. 1). 629 pp. Paper, $1.95.

Calculus Refresher for Technical Men. A. Albert Klaf. Dover, New York, 1956 (unabridged republication of ed. 1). 431 pp. Paper, $1.95.

Must Men Starve? The Malthusian controversy. Jacob Oser. Abelard-Schuman, New York, 1957. 331 pp. $4.50.

Modern Methods of Microscopy. A series of papers reprinted from *Research.* A. E. J. Vickers. Butterworths, London, 1956. 114 pp. $3.50.

Progress in the Chemistry of Organic Natural Products. vol. 13. L. Zechmeister, Ed. Springer, Vienna, 1956. 624 pp. $25.60.

Lymphatics, Lymph and Lymphoid Tissue. Joseph M. Yoffey and Frederick C. Courtice. Harvard University Press, Cambridge, 1956. 510 pp. $10.

Franklin and His French Contemporaries. Alfred O. Aldridge. New York University Press, New York, 1957. 260 pp. $4.75.

The Great Chain of Life. Joseph W. Krutch. Houghton Mifflin, Boston, 1957. 227 pp. $3.75.

Natural History of Birds. A guide to ornithology. Leonard W. Wing. Ronald Press, New York, 1956. 539 pp. $6.75.

Heredity and Your Life. An account of everyday human inheritance. A. M. Winchester. Vantage Press, New York, 1956. 333 pp. $5.

Pharmacognosy. Edward P. Claus, Ed. Lea & Febiger, Philadelphia, ed. 3, 1956. 731 pp. $12.50.

Intercrossing among Pink Calla, White-Spotted Calla and Yellow Calla. Ryohitsu Shibuya. The Author, 1430 Grant Rd., Mountain View, Calif., 1956. 62 pp.

Electronic Computers, Principles and Applications. T. E. Ivall. Iliffe, London; Philosophical Library, New York, 1956. 167 pp. $10.

Straight to the Heart. A personal account of thoughts and feelings while undergoing heart surgery. George Lawton. International Universities Press, New York, 1956. 347 pp. $5.

Mind and the World-Order. Clarence I. Lewis. Dover, New York, 1956 (unabridged republication of ed. 1). 446 pp. Paper, $1.95.

Perspectives in Personality Theory. Henry P. David and Helmut von Bracken. Basic Books, New York, 1957. 435 pp. $6.50.

Franklin and Newton. An inquiry into speculative Newtonian experimental science and Franklin's work in electricity as an example thereof. I. Bernard Cohen. American Philosophical Society, Philadelphia, 1956. 657 pp. $6.

The Structure of a Moral Code. A philosophical analysis of ethical discourse applied to the ethics of the Navaho Indians. John Ladd. Harvard University Press, Cambridge, 1957. 474 pp. $8.

Breads, White and Brown. Their place in thought and social history. R. A. McCance and R. M. Widdowson. Lippincott, Philadelphia, 1956. 174 pp. $5.

Fatigue in Aircraft Structures. Proceedings of the International Conference held at Columbia University, 30 Jan.–1 Feb. 1956. Alfred M. Freudenthal, Ed. Academic Press, New York, 1956. 456 pp. $12.

Structure of Rings. American Mathematical Society Colloquium Publ., vol. XXXVII. Nathan Jacobson. American Mathematical Society, Providence, R. I., 1956. 263 pp. $7.70.

Principles and Problems of Modern Economics. William A. Koivisto. Wiley, New York; Chapman & Hall, London, 1956. 834 pp. $6.

The Liassic Therapsid Oligokyphus. Walter G. Kuhne. British Museum (Natural History), London, 1956. 149 pp. £4.

Ageing in Industry. An inquiry, based on figures derived from census reports, into the problem of ageing under the conditions of modern industry. F. Le Gros Clark and Agnes C. Dunne. Philosophical Library, New York, 1956. 150 pp. $7.50.

Administrative Medicine. Transactions of the Fourth Conference, 31 October–2 November 1955, Princeton, N.J. George S. Stevenson, Ed. Josiah Macy, Jr. Foundation, New York, 1956. 251 pp. $4.25.

Cellular Mechanisms in Differentiation and Growth. Fourteenth symposium of the Society for the Study of Development and Growth. Dorothea Rudnick, Ed. Princeton University Press, Princeton, N.J., 1956. 236 pp. $7.50.

Elements of Algebra. Howard Levi. Chelsea, New York, ed. 2, 1956. 160 pp. $3.25.

General Genetics. M. J. Sirks. Translated by Jan Weijer and D. Weijer-Tolmie. Nijhoff, The Hague, 1956. 628 pp. G.35.

Jews in the World of Science. A biographical dictionary of Jews eminent in the natural and social sciences. Harry Cohen and Itzhak J. Carmin. Monde, New York, 1956. 264 pp.

Studies in Differential Equations. Series in Mathematical and Physical Sciences, No. 3. Harold T. Davis, Ed. Northwestern University Press, Evanston, Ill., 1956. 114 pp. $1.75.

CERN Symposium on High Energy Accelerators and Pion Physics, Proceedings. Geneva, 11–23 June 1956. vol. 1, *High Energy Accelerators;* 567 pp.; F. 40. vol. 2, *Pion Physics;* 443 pp.; F. 40. Organization for Nuclear Research, Geneva, 1956.

Education and Human Motivation. H. Harry Giles. Philosophical Library, New York, 1957. 108 pp. $3.

An Introduction to Cybernetics. W. Ross Ashby. Wiley, New York, 1956. 295 pp. $6.50.

Wildlife Law Enforcement. William F. Sigler. Brown, Dubuque, Iowa, 1956. 318 pp. $4.50.

Dictionary of Anthropology. Charles Winick. Philosophical Library, New York, 1956. 579 pp. $10.

In the Last Analysis. Adam E. Armstrong. Philosophical Library, New York, 1956. 115 pp. $3.

Psychology. General, industrial, social. John M. Fraser. Philosophical Library, New York, 1956. 310 pp. $7.50.

Wire Brush Surgery. In the treatment of certain cosmetic defects and diseases of the skin. James W. Burks, Jr. Thomas, Springfield, Ill., 1956. 154 pp. $6.75.

Glaucoma. Transactions of the First Conference, 5–7 December, 1955, Princeton, N. J. Frank W. Newell, Ed. Josiah Macy, Jr. Foundation, New York, 1956. 251 pp. $4.50.

Lectures in Immunochemistry. Michael Heidelberger. Academic Press, New York, 1956. 150 pp. $4.

Chain Reactions, an Introduction. F. S. Dainton. Methuen, London; Wiley, New York, 1956. 183 pp. $2.90.

A Million Years of Human Progress. Ira D. Cardiff. Pageant Press, New York, rev. ed., 1955. 146 pp. $2.50.

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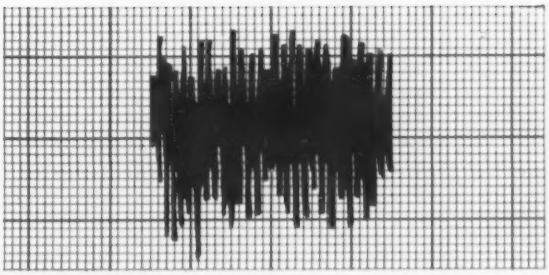

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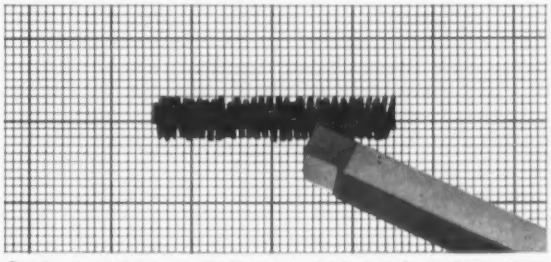

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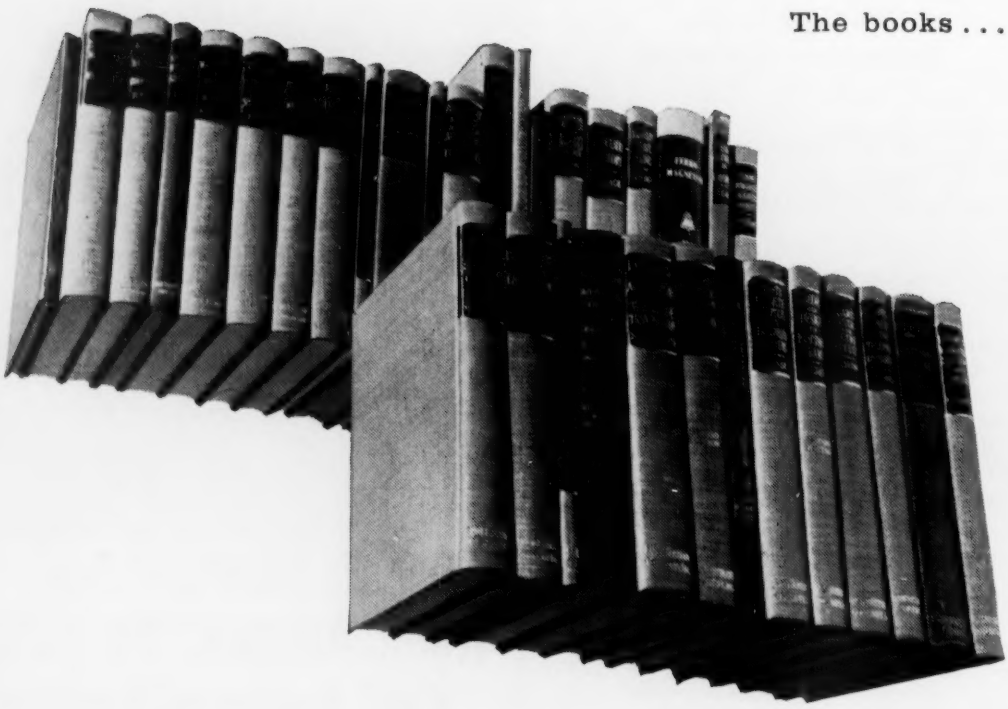

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(*Continued from page 164*)

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Solid State Physics. Advances in research and application. vol. III. Frederick Seitz and David Turnbull, Eds. Academic Press, New York, 1956. 588 pp. $12.

Theory of Land Locomotion. M. G. Bekker. University of Michigan Press, Ann Arbor, 1956. 520 pp. $12.50.

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Spot Tests in Organic Analysis. Fritz Feigl. Translated by Ralph E. Oesper. Elsevier, Amsterdam, ed. 5, enl. and rev., 1956. 616 pp. $11.

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Textbook of Entomology. Herbert H. Ross. Wiley, New York; Chapman & Hall, London, ed. 2, 1956. 519 pp. $7.75.

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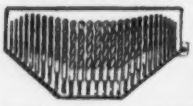

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Meetings

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25–29. International College of Allergy, 3rd symp., London, England. (W. Kaufman, 540 Brooklawn Ave., Bridgeport 4, Conn.)

26–28. Mechanisms for the Development of Drug Resistance in Microorganisms, Ciba Foundation Symp. (by invitation), London, England. (G. E. W. Wolstenholme, 41 Portland Pl., London, W.1.)

26–28. Weather Radar Conf., 6th, sponsored by American Meteorological Soc., Cambridge, Mass. (K. C. Spengler, 3 Joy St., Boston 8, Mass.)

27–29. American Power Conf., 19th annual, Chicago, Ill. (R. A. Budenholzer, Illinois Inst. of Technology, 35 W. 33 St., Chicago 16.)

27–29. Effects of Radiation on Materials, colloquium, Baltimore, Md. (Office of Naval Research, Glenn L. Martin Co., Baltimore 3.)

27–29. National Committee on Alcoholism, annual, Chicago, Ill. (Miss E. Jensen, NCA, 2 E. 103 St., New York 29.)

April

1–4. American Assoc. of Petroleum Geologists, 42nd annual, St. Louis, Mo. (R. H. Dott, AAPG, Box 979, Tulsa, Okla.)

1–4. International Anesthesia Research Soc., cong., Phoenix, Ariz. (A. W. Friend, Wade Park Manor, Cleveland 6, Ohio.)

1–4. Society of Economic Paleontologists and Mineralogists, annual, St. Louis, Mo. (S. P. Ellison, Jr., Dept. of Geology, Univ. of Texas, Austin.)

1–5. Assoc. of American Geographers, annual, Cincinnati, Ohio. (B. W. Adkinson, Reference Dept., Library of Congress, Washington 25.)

2–3. Future Developments in Food Preservation, symp., Kansas City, Mo. (Food Symposium, Midwest Research Inst., 425 Volker Blvd., Kansas City 10.)

4–5. Dietary Fats—Helpful or Harmful, 3rd annual nutrition conf., Detroit, Mich. (A. H. Smith, Wayne State Univ. College of Medicine, Detroit 7.)

5–6. American Mathematical Soc., New York, N.Y. (J. H. Curtiss, AMS, 190 Hope St., Providence 6, R.I.)

7–10. Pan American Assoc. of Ophthalmology, 4th interim cong., New York, N.Y. (B. F. Payne, 17 E. 72 St., New York 21.)

7–12. American Chemical Soc., Miami, Fla. (A. H. Emery, ACS, 1155 16 St., NW, Washington 6.)

8. Phi Lambda Upsilon, Miami, Fla. (T. B. Cameron, Dept. of Chemistry, Univ. of Cincinnati, Cincinnati 21, Ohio.)

8–10. American Soc. of Mechanical Engineers, spring, Birmingham, Ala. (C. E. Davies, ASME, 29 W. 39 St., New York 18.)

8–12. Food Bacteriology, internatl. symp., Cambridge, England. (Dr. Mossel, Central Inst. for Nutrition Research T.N.O., Catharijnesingel 61, Utrecht, Netherlands.)

8–12. Surface Activity, 2nd world cong., London, England. (Congress Secy., 14 Belgrave Sq., London, S.W.1.)

9–10. Industrial Electronics Education Conf., annual, Chicago, Ill. (E. A. Roberts, Armour Research Foundation, Illinois Inst. of Technology, Chicago 16.)

10–12. Nuclear Instrumentation Conf., natl., Atlanta, Ga. (H. Kindler, Instrument Soc. of America, 313 Sixth Ave., Pittsburgh, Pa.)

10–13. Conf. on Embryology and Experimental Morphology, Cambridge, England. (D. R. Newth, Dept. of Zoology, University College London, Gower St., London, W.C.1.)

11–13. American Assoc. of Pathologists and Bacteriologists, annual, Washington, D.C. (E. A. Gall, Cincinnati General Hospital, Cincinnati 29, Ohio.)

11–13. Southwestern Inst. of Radio Engineers Conf. and Electronics Show, 9th annual, with 2nd National Simulation Conf., Houston, Tex. (F. C. Smith, Jr., Box 13058, Houston 19.)

12–13. Colorado–Wyoming Acad. of Science, annual, Fort Collins, Colo. (O. W. Olsen, Colorado A.&M. College, Fort Collins.)

12–13. Eastern Psychological Assoc., annual, New York, N.Y. (G. G. Lane, Dept. of Psychology, Univ. of Delaware, Newark.)

12–13. New Orleans Acad. of Sciences, New Orleans, La. (A. Welden, Dept. of Biology, Newcomb College, New Orleans.)

12–14. American Assoc. for Cancer Research, Chicago, Ill. (H. J. Creech, Inst. for Cancer Research, Fox Chase, Philadelphia 11, Pa.)

12–14. American Assoc. of Physical Anthropologists, annual, Ann Arbor, Mich. (J. H. Spuhler, Dept. of Human Genetics, Univ. of Michigan Medical School, Ann Arbor.)

12–14. American Soc. of Human Genetics, annual, Ann Arbor, Mich. (E. J. Gardner, Dept. of Zoology, Utah State College, Logan.)

12–14. National Speleological Soc., Natural Bridge, Va. (Mrs. M. McKenzie, 1407 Hickory Ct., Broyhill Park, Falls Church, Va.)

13. Society for the Scientific Study of Religion, spring, New York, N.Y. (W. C. Clark, Hartford School of Religious Education, Hartford 5, Conn.)

13. South Carolina Acad. of Science, annual, Columbia. (Miss M. Hess, Box 114, Winthrop College, Rock Hill, S.C.)

14–16. Telemetering Symposium, natl., Philadelphia, Pa. (A. S. Westneat, Jr., Applied Science Corp., Box 44, Princeton, N.J.)

14–20. American Physiological Soc., Chicago, Ill. (M. O. Lee, APS, 9650 Wisconsin Ave., NW, Washington 14.)

15–17. Molecular Mechanism of Rate Processes in Solids, Faraday Soc. discussion, Amsterdam, Netherlands. (Faraday Soc., 6 Gray's Inn Sq., London, W.C.1.)

15–17. Systems for Information Retrieval, symp., Cleveland, Ohio. (J. H. Shera, School of Library Science, Western Reserve Univ., Cleveland 6.)

15–18. American Personnel and Guidance Assoc. and constituent divisions: American College Personnel Assoc., American School Counselor Assoc., National Assoc. of Guidance Supervisors and Counselor Trainers, National Vocational Guidance Assoc., Student Personnel Assoc. for Teacher Education; Detroit, Mich. (A. A. Hitchcock, APGA, 1534 O St., NW, Washington 5.)

15–18. Host-Specificity and Parallel Evolution among Parasitic Insects and Worms, symp., Neuchatel, Switzerland. (J. G. Baer, C.P. 2, Neuchatel 7.)

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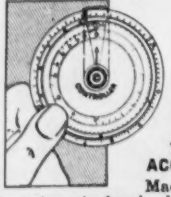

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15–18. International Institute of Differing Civilizations, 30th session, Lisbon, Portugal. (11, Blvd. de Waterloo, Brussels, Belgium.)

15–19. American Assoc. of Immunologists, annual, Chicago, Ill. (F. S. Cheever, Graduate School of Public Health, Univ. of Pittsburgh, Pittsburgh 13, Pa.)

15–19. American Soc. for Experimental Pathology, annual, Chicago, Ill. (C. C. Erickson, Inst. of Pathology, Univ. of Tennessee, 858 Madison Ave., Memphis.)

15–19. American Soc. for Pharmacology and Experimental Therapeutics, Chicago, Ill. (H. Hodge, Dept. of Pharmacology, Univ. of Rochester, Rochester, N.Y.)

15–19. Federation of American Societies for Experimental Biology, annual, Chicago, Ill. (M. O. Lee, FASEB, 9650 Wisconsin Ave., Washington 14.)

15–19. High Energy Nuclear Physics Conf., 7th annual, Rochester, N.Y. (R. Marshak, Univ. of Rochester, Rochester.)

15–20. American Inst. of Nutrition, annual, Chicago, Ill. (R. W. Engel, Dept. of Biochemistry and Nutrition, Virginia Polytechnic Inst., Blacksburg 13.)

16–18. Nuclear Tests for Nondestructive Testing Applications, symp., Chicago, Ill. (American Soc. for Testing Materials, 1916 Race St., Philadelphia 3, Pa.)

17–19. American Assoc. of Anatomists, annual, Baltimore, Md. (L. B. Flexner, School of Medicine, Univ. of Pennsylvania, Philadelphia 4.)

18–20. Assoc. of Southeastern Biologists, annual, Athens, Ga. (J. C. Dickinson, Jr., Univ. of Florida, Gainesville.)

18–20. Ohio Acad. of Science, annual, Bowling Green. (R. W. Dexter, Dept. of Biology, Kent State Univ., Kent, Ohio.)

18–20. Southern Soc. for Philosophy and Psychology, annual, Gatlinburg, Tenn. (W. W. Webb, U.S. Navy School of Aviation Medicine, Pensacola, Fla.)

18–20. Venereal Disease Postgrad. Conf., 26th, Memphis, Tenn. (H. Packer, Dept. of Preventive Medicine, Univ. of Tennessee College of Medicine, Memphis 3.)

19–20. Arkansas Acad. of Science, annual, Fayetteville. (L. F. Bailey, University of Arkansas, Fayetteville.)

19–20. Seismological Soc. of America, annual, Los Angeles, Calif. (P. Byerly, Bacon Hall, Univ. of California, Berkeley 4.)

22–24. National Acad. of Sciences, annual, Washington, D.C. (H. L. Dryden, NAS, 2101 Constitution Ave., NW, Washington 25.)

23–25. Chemistry and Biology of Mucopolysaccharides, Ciba Foundation Symp. (by invitation only), London, England. (G. E .W. Wolstenholme, 41 Portland Pl., London, W.1.)

23–25. Solid State Devices in Electric Circuits, symp., New York, N.Y. (J. Griesmann, Microwave Research Inst., 55 Johnson St., Brooklyn 1, N.Y.)

23–26. American Industrial Hygiene Assoc., annual, St. Louis, Mo. (G. D. Clayton, AIHA, 14125 Prevost, Detroit 27, Mich.)

23–27. Separation of Isotopes, colloquium of IUPAP, Amsterdam, Netherlands. (J. Kistemaker, Laboratorium voor Massaspectrografie, Hoogfe Kadijk 202, Amsterdam C.)

24–25. Recent Advances in the Study of Venereal Disease, 8th annual symp., Washington, D.C. (W. J. Brown, Program Committee Chairman, Communicable Disease Center, Atlanta, Ga.)

25–27. American Physical Soc., Washington, D.C. (K. K. Darrow, APS, Columbia Univ., New York 27, N.Y.)

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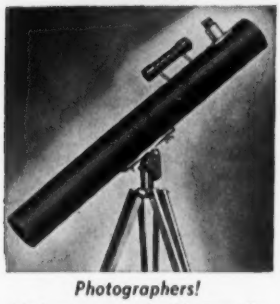

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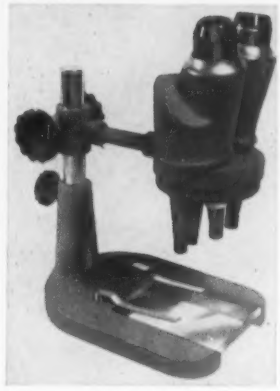

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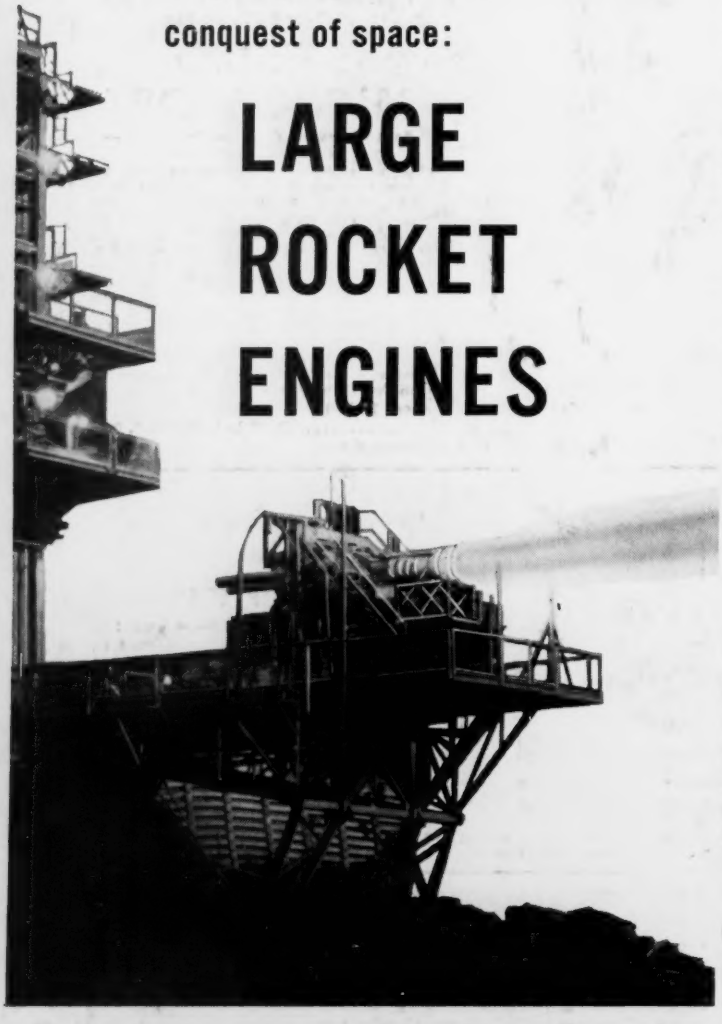

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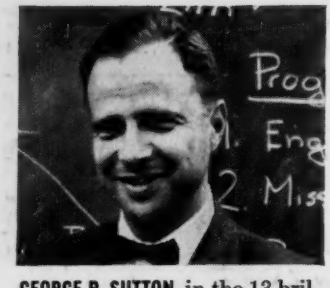
WILLIAM J. CECKA, JR., 35, aeronautical engineer, (Univ. of Minn. '43), was called from North American by the Air Force for experimental rocket work in 1944. On his return, he progressed rapidly: 1948, supervisory test job; 1950, group engineer, operations; 1953 engineering group leader; 1955, section chief of engineering test. Using our refund plan, he has his M.Sc. in sight.



GEORGE P. SUTTON, in the 13 brilliant years since receiving his MSME, Cal Tech, has made rocketry a way of life. His reputation is world wide. His book *Rocket Propulsion Elements* is recognized as the standard text on the subject. Still active academically, but no bookworm, he takes time off occasionally to study the laws of motion at some of the world's better ski resorts.

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